



# Proceedings of the **Next Generation Exploration Conference**



**Next Generation  
Exploration**  
C O N F E R E N C E

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Emerging global space leaders designing  
the future of space exploration.

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Proceedings of a conference sponsored by the  
National Aeronautics and Space Administration  
held at NASA Ames Research Center  
Moffett Field, California  
August 16 - 18, 2006



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# Proceedings of the Next Generation Exploration Conference

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### A Letter from the Editors

The Next Generation Exploration Conference (NGEC) brought together the emerging next generation of space leaders over three intensive days of collaboration and planning. The participants extended the ongoing work of national space agencies around the world to draft a common strategic framework for lunar exploration, to include other destinations in the solar system. NGEC is the first conference to bring together emerging leaders to comment on and contribute to these activities. The majority of the three-day conference looked beyond the moon and focused on the “next destination”: Asteroids, Cis-Lunar, Earth 3.0, Mars Science and Exploration, Mars Settlement and Society, and Virtual Worlds and Virtual Exploration.

Three participants from each group were further given the opportunity to demonstrate their leadership skills through moderation and rapporteur responsibilities, resulting in a conference attended, organized, and executed by peers. As one participant observed, the major difference between this conference and any other within the space sector was that over 90% of participants were on their computers contributing content real-time via online, collaborative tools.

This conference demonstrated the power not just of tomorrow’s leaders but also of the tools and technologies that NASA is beginning to employ to engage people in and accomplish its mission. By the time humanity gets to the moon, mars, asteroids and beyond, it will be in a networked, transparent, and socially responsible fashion. This reflects the importance of engaging young people early in planning for the next generation of space exploration. In doing so, one leverages not just their passion and drive, but their entire worldview and mode of operations—which is quicker, more participatory, and more demanding than ever before.

This proceedings book is a compilation of the intense activities during the three days of the conference. Many lessons were learned in this process, and we look forward to implementing them in the next ‘NGEC-like’ conference.

We would like to thank the NASA’s Exploration Systems Mission Directorate (ESMD) for contributing financially to making this conference possible, and in particular to Tom Cremins, Debbie Scrivner, and Jeff Volosin. The staff at NASA Ames Research Center (ARC) was incredibly helpful in making NGEC a success and we would like to thank Rho Christensen, Karen Bradford and Shirley Berthold for their leadership and unparalleled support. We would also like to thank Tek Okimura for his technical and computer support that made it possible for the participants to work with real-time, collaborative tools. There were non-United States participants during this workshop, and we would like to thank ESMD for their support, the ARC international visitor shirley Berthold, and Garvey McIntosh in the Office of External Relations at NASA Headquarters for enabling international participants on such a short notice. The thought-leaders behind the idea of NGEC were participants at the April 2006 ESMD Exploration Strategy Workshop and we would particularly like to thank Loretta Hidalgo Whitesides and friends within the Space Generation community. We would

#### Attendees at NGEC

166 people total  
Average age 28  
24% international  
32% students  
45% NASA civil servants and contractors  
Countries (16)--Italy, Japan, Canada, France, China, Australia, Spain, Germany, Turkey, Norway, the Netherlands, Ireland, India, Switzerland, United Kingdom, South Africa

like to thank all the speakers for taking the time to teach and guide the NGEC participants during the conference. The participants, moderators and rapporteurs themselves contributed tirelessly during the three days, and we would explicitly like to thank Audrey Shaeffer for her assistance in liaising with ESMD and editing all the chapters within these proceedings. We would also like to thank Benjamin Sanders for an excellent job co-moderating the Mars Settlement and Society, JoHanna Przybylowski for rapporteuring the Virtual Worlds and Virtual Exploration working group and her leadership in writing and editing their contribution, and Alexandre Lasslop, Michael Collie, and Maraia Hoffman for leading the development of the NGEC Forward and NGEC Declaration. We would like to thank Jennifer Bailey as the NGEC conference manager for devoting over two-months to realizing this conference and Julie Fletcher for the design and layout of these proceedings. Finally, we would like to thank the NASA Ames Research Center Director Pete Worden for his vision in allowing the next generation of explorers to become leaders sooner.

The block contains two handwritten signatures in black ink. The signature on the left is 'Robert Fisher' and the signature on the right is 'Kernda Lynch'. They are positioned side-by-side.

26 September 2006

*"Man must rise above Earth  
to the top of the atmosphere  
and beyond,  
for only then will he  
fully understand the world  
in which he lives."  
Socrates (470-399 B.C.)*

Socrates uttered these words over two thousand years ago and they continue to be just as relevant today. But these days, wonder at the night sky is not enough to sustain public interest in the space program. Much of the public feels that we have already discovered the 'new continent' of space and that the most important advancements are behind us. Today's people have demonstrated that they are more concerned with the problems of today than the possibilities of tomorrow.

As such, the global space community is faced with finding a new reason for being. This is the topic of conversation that dominated much of NASA's Exploration Systems Mission Directorate (ESMD) sponsored Next Generation Exploration Conference (NGEC) held August 16th to 18th, 2006. Over 160 of the youngest and brightest emerging space leaders, from more than 15 countries came together to collectively pool their talents and skills with the intent to provide the global space community honest feedback in regards to its current strategies.

We were divided into six groups each looking at a future 'destination' for exploration. The findings of these discussion groups are laid out in the following pages, however it was that the heart of various discussions surrounded the question of how the global space effort could again become a source of imagination and the hope for a brighter future.

How can the global space program reinvent itself as necessary in today's culture and in the current political and economic climates? Our answer: become a solution. Here are several ways space programs can create themselves as the answer to the greatest national and international challenges and in doing so increase the likelihood of a long and prosperous future:

**#1 - Create a new economic market: Partner with private industry to pioneer new technologies, revenue streams and energy solutions in space.**

- Help create financial incentives for private industry to explore space. For the foreseeable future, the 21st century appears to have similar incentive structures: Where it is possible to make money, growth will follow. Can some activities within government space agencies be privatized? How much more hard science necessary for extra-terrestrial living could be funded if desired objectives were given to economically beneficial projects to private industry?

- Is there a solution to our power crisis using space technology? How can space agencies use space and private industry as a way to be a solver of this problem?
- Evidence suggests there are thousands of Near Earth Asteroids (NEAs) rich in metals, water and/or organic materials that may be cost effective to harvest.
- Create an arm of each space agency dedicated to finding and inspiring applications of current scientific research. Leverage the economic drive of the private industry to maximize technological growth. Ensure the public is aware of exploration-derived technology by developing brand stickers (such as those found on most laptops, Intel inside, for example).

An entirely new industry is in the process of emerging. Why not ensure exploration's future by becoming the focal point and prime supporter of the inevitable move to private space travel and exploration?

**#2 - Science as Allegiance: The search for scientific truth has throughout history proven to be a powerful allegiance, how can we leverage this to exploration's advantage?**

- Establish an international advisory body, consisting of young professionals, scientists and space agency outsiders of multiple disciplines (including art, music, philosophy, etc) to provide regular updates and recommendations. Allow space agency officials to attend these meetings as the live verbal dialogue is far more effective than a written summary. The money is being spent, why not get the full value?
- Promote the idea that Earth is not separate from Space. What we learn 'out there' profoundly affects our life on Earth. "Space is the journey we all benefit from, not the destination of a few."

**#3 - Lead our global community in solving educational crises with the intention of promoting science and technology.**

- Education is the avenue by which we can inspire the world. In the sixties space was a new frontier, today it is not as exciting for most people. Trying to engage the public in the same way exploration did several decades ago is a losing proposition. Education is a problem everyone in the world is aware of, let us light the public up by lighting up their children.
- Space has always been a source of amazement to children. Sponsor programs that powerfully motivate and inspire. Be known not as the creator of the curriculum, but the benefactor of programs that are already making a difference. Why reinvent the wheel?
- Create a mentor program for students and young professionals. Provide incentives for those individuals already in the space industry to pass on their knowledge and skill sets to the next generation so that their expertise is not lost at retirement.

- ‘Virtual worlds’ offer the opportunity to shatter the barriers to collaboration and participation by providing worldwide access to comprehensive modeling tools, contextual databasing, and interactive collaboration forums. Virtual worlds have the power to tap currently underutilized resources and ideas, resulting in an inclusive community of explorers, ranging from kindergarten classrooms to career researchers, all contributing to a common goal.

We highly recommend that global space agencies redefine themselves in terms of the problems they can solve today in addition to the dreams they can realize tomorrow.

It is in the spirit of recognizing that extreme endeavors such as space exploration require the cooperation of multiple generations, the collaboration of space faring nations with those soon space bound and the teamwork of governmental space agencies along with private industry, that we humbly offer the above recommendations.

*With this in mind, we also want to point out the credo of respect which should never be lost out of sight while our species explores and expands into our surrounding Universe :*

*“Human beings want and should explore the solar system and beyond, and do so in an ethical way, in order to understand, protect, preserve and expand all lifeforms – including our own - and move from scientific-driven exploration to a new multi-planetary society”*

Everyone present at the 2006 Next Generation Exploration Conference strongly supports international space exploration. We thank NASA’s Exploration Systems Mission Directorate many times over for the opportunity to contribute to the most esteemed space endeavor in human history. We have been honored and inspired by the request for input.

May our involvement help to deliver the magnificent future we all imagine.



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# **Executive Summary** from the **Next Generation Exploration Conference**

22 September 2006

Over 160 professionals from 16 countries representing diverse occupations including scientists, educators, philosophers, entrepreneurs, and futurists met at NASA Ames Research Center from 16 to 18 August 2006 with the support of NASA's Exploration Systems Mission Directorate (ESMD) to discuss the long-term goals of space exploration. These stakeholders addressed six 'destinations' for future extensive exploration: asteroids, the cis-lunar (near-lunar) environment, Earth 3.0 (the likely state of future Earth), Mars science and exploration, Mars settlement and society, and virtual exploration. Based on the deliberations and opinions, the participants have prepared the following statement and recommendations:

**Asteroids** - The economic potential of thousands of near-earth asteroids (NEAs) will help to support future exploration endeavors and human presence in space. Strong evidence suggests that NEAs are rich in metals, water, and /or organic materials, and reaching them will require relatively low fuel costs. Extracted materials from the NEAs can be used to manufacture structures, fuel, and other resources for mankind's exploration of the solar system. In addition, NEAs have a large range of orbits, essentially making them into traveling resource platforms which also can be used for low-energy transportation and scientific study of our solar system. Finally, as history has proven, NEAs can collide with Earth and have potentially catastrophic consequences to life and infrastructure. Exploration and understanding of asteroids is essential to humanity's future, both on Earth and in space.

**Cis-Lunar** – Space agencies are committed to the “safe, sustained, affordable human and robotic exploration of the Moon, Mars, and beyond.” However, we recommend that they explicitly define our ultimate goal and motivation in order to portray a sense of purpose to the public. Our goal is sustainable human settlement of the Moon and Mars and our motivation is to preserve the human race. All secondary exploration and science objectives flow from this main goal and are still imperative to our success. As an economic guiding principle, governments should be limited to those areas where only government can perform the activity and should recognize and coordinate with the larger private and military sectors. Also, space agencies must continue to fund the interdisciplinary science necessary to characterize environmental hazards associated with dust, radiation, surface charging, topology, and meteorites in order to make our first attempts at extraterrestrial living viable.

**Earth 3.0** – We believe that as humanity increases its ability to design its environment and develop new biological and artificial intelligences the need to assimilate these diverse elements into a congruent and intended societal structure is essential. In exploring the many possibilities of emerging intelligences we found a critical need for a dominant form of communication that would transcend language barriers. Although the same need exists currently, in a future where humanity is but a subset and Artificial Intelligence, Cybernetic individuals, and other intelligent life exists, a “language” that communicates intent rather than vocabulary will not only be a necessity but an opportunity to engender personal empowerment and responsibility in the creation of our own reality. In doing so, we for the first time in history have the ability to deliberately sculpt a truly inspiring future.

**Mars Science and Exploration** - Scientific discovery and technological development drives human advancement, and Mars provides a unique and vital destination for such research. In addition, the exploration of Mars can provide significant social benefits back on Earth. International cooperation will not only be essential to the success of a human presence on Mars, but development of such processes would jumpstart collaboration on global issues. The eventual commercialization of space holds tremendous opportunities for economic growth. Furthermore, there is an undeniable basic human need to explore and define our place in the universe. The overarching theme that ties together all of these reasons for exploration is inspiring and uniting the global community. Continuously inspiring the public, the scientific community, and the community of Earth is required in order to achieve the goals of Mars science and exploration.

**Mars Settlement and Society** – Humans have an innate need to explore and expand their knowledge of the Universe. We envision a future where humans not only visit Mars for short periods of time to conduct discrete scientific and business projects, but a future where humans live long-term productive lives beyond the confines of Earth. The Mars Settlement and Society group therefore focused on five key areas, with the understanding that this long-term implication of Mars exploration must be considered early in the process, in order to assure final success: Human Subsystems, Habitat Design, Community Infrastructure/Government, Creating Stakeholders, and Philosophical Framework. It was obvious for all study groups of those areas - which shared the common drive to engage, inspire, and educate the public in order to create true stakeholders for the human exploration of the Solar System – that a number of such crucial topics as legal and governing systems, group dynamics and psychology, issues of reproduction and human development, and the creation of a strong philosophical framework for Mars exploration still needed to be well researched. We have to be aware that it is these objectives, which do permit us to focus on both long-term goals and near-term tasks, that will prepare us to arrive at and, more importantly, to stay on Mars. Therefore these objectives and themes should be important parts of an international dialogue on exploration strategies.

**Virtual Worlds and Virtual Exploration** - Virtual worlds will forever alter the landscape of exploration, revolutionizing every aspect of research, design, implementation and resolution, shattering the barriers to collaboration and participation. By providing worldwide access to comprehensive modeling tools, contextual databasing, and interactive collaboration forums, virtual worlds will tap currently underutilized resources and ideas, resulting in an inclusive community of explorers, consisting of everyone from kindergarten classrooms to career researchers contributing to a common goal.

In recognition that achieving the goals of international space exploration requires cooperation between older and younger generations, between nations with a history of manned exploration and those soon to have one, as well as between space agencies and the general public, we have identified the a number of issues which warrant considerable attention. For progress to be made, we outline the issues and propose some solutions to them:

- Funding opportunities and procedures are currently not adequate for ensuring the successful completion of humanity's first step into the exploration of our solar system: The return to the Moon and the setup of capacity for long-term missions on its surface. Funding opportunities for lunar science should recognize its interdisciplinary nature, resist the "old-fashioned" approach to fund traditional areas of study, and are should be comparable in size to that of the Mars program. It is important that space agencies keep supporting the science that characterizes the lunar environment.

- The public does presently not feel engaged in the space conversation. The utilization of non-standard means of public outreach by the space agencies, as well as additional tools at their disposal, might enable them to recover the public's attention and interest. Two-way communication and allowing the public to participate in space exploration activities in a meaningful way will gain more public support for the goals of space exploration.
- In order to achieve the primary goal of permanent self sufficient settlement, the utilization of commercial resources is crucial. Therefore space agencies need to be at the forefront of this adaptation of the space sector and advocate with their political leaders the necessity to find an internationally agreed solution to the legal uncertainty which currently exists. Their role in this new era, is to engage and favor the involvement of the private sector right from the outset, support the private space business and the commercial development of space technologies, and therefore to identify a clear transition plan away from the 20th century when governments exclusively run space exploration programs.
- The exploration and expansion of humanity into our nearby solar system and eventually beyond has to be done in respect of the unique environments we encounter. It is important for the international community to review and adapt the planetary protection protocols currently in use in regards to this new endeavor.
- Space agencies – at least in the western world – do have a tendency to see the mean age of their employees to move away from the profile present at the early stages of space exploration. An international, interdisciplinary advisory body composed of young professionals and scientists, which meet regularly (on an annual or bi-annual basis), will ensure that a close contact is held between the space agencies and commercial interests, and those currently driving the exploration goals.
- Various stakeholders are not aware of the potential benefits which can be gained from conducting space exploration. For example, the inherent beneficial characteristics of Near-Earth Asteroids which enable early, sustainable exploration of the inner solar system has to be promoted to policy-makers, the public, engineers and scientists.
- Some criticize permanent presence on other celestial bodies as "giving up" on Earth. Space agencies need to promote the protection and extended understanding of our home planet through a comprehensive focus on scientific research that incorporates both the physical and life sciences.
- Space agencies should develop the 'language' of the future: a way of communicating intent, rather than vocabulary. Although the concept may appear relatively abstract, the necessity is real as is the possibility of its creation.

As members of the generation that will have, in our lifetimes, both the responsibility and empowerment to realize the installation of man on the Moon, as well as the initial stages of the extension of civilization into our solar system, we encourage space agencies and other stakeholders to act on our suggestions early in this process. We all enthusiastically look upward to the heavens and forward to the future as we work together, in an international effort, to progress toward the future of humanity.

# **Letter to ESMD from the Next Generation Exploration Conference**

Doug Cooke  
 Deputy Associate Administrator,  
 Exploration Systems Mission Directorate  
 National Aeronautics and Space Administration  
 300 E Street SW  
 Washington, DC, 20546



September 5, 2006

Almost 170 “next generation” space professionals and students gathered at the NASA ESMD-sponsored Next Generation Exploration Conference (NGEC), held at NASA Ames Research Center August 16-18. As participants of the NGEC, we commend NASA on supporting this event and soliciting our feedback on the interim Global Lunar Exploration Strategy.

As the “next generation,” we are currently in the early phases of our careers in the space sector. Over time, however, we will become the leaders and managers of space exploration activities. Therefore, we consider ourselves critical stakeholders in the current strategy development.

Based on the comments of six working groups, we offer the following overall recommendations for Global Exploration Strategy development, in addition to the detailed inputs we have already provided to the Lunar Exploration Themes and Objectives. Briefly, our recommendations are:

- Engage additional stakeholder groups in the global strategy development. For some groups, special attention must be made to overcome barriers to participate. Ensure that feedback about the strategy is provided to all stakeholders in a timely manner.
- Define a higher-level rationale for space exploration than what is currently outlined in the Lunar Exploration Themes. This rationale should explain why the global community should explore and settle space, using reasons relevant to humanity.
- Continue to engage the “next generation” in strategy development and mission planning. Individuals currently in the early phases of their careers will move into leadership roles as we execute the Global Exploration Strategy that we define today.

Each of these recommendations is outlined further in the attached appendix.

The NGEC participants thank NASA for providing our generation with the opportunity to engage in the development of a Global Exploration Strategy. We consider the NGEC a first step in involving future generations in planning the path to tomorrow. Because we are taxpayers, voters, and the future decision-makers, we hold the destiny of space exploration in our hands. Engaging our generation today will be critical for continuing the exploration journey tomorrow.

On behalf of the participants of the  
 Next Generation Exploration Conference,

Robbie Schingler  
 NGEC Organizer, NASA Ames Research Center

CC:  
 Inst Assets and Invest Ofc/Mr. Cremins  
 Public Outreach Manager/Ms. Scrivner  
 Mission Ops and Integration Ofc/Mr. Volosin  
 Director, Ames Research Center/Dr. Worden



## Next Generation Exploration Conference

### Response to NASA Exploration Systems Mission Directorate:

*Recommendations regarding the development of a Global Exploration Strategy*

#### **Engage Additional Stakeholder Groups**

To ensure a sustainable exploration program, stakeholders from across the space arena must be engaged, beginning today with the development of the Global Lunar Exploration Strategy. We have identified important stakeholder groups that seem to have been underrepresented thus far in developing the strategy. Engaging these groups further will encapsulate a broader set of perspectives, creating a more thorough, refined, and robust strategy.

We recommend additional participation by the groups described below, possibly via a forum similar to the NGENC and April 2006 Exploration Strategy Workshop. Whatever the method, however, early involvement of these groups will result in a more developed strategy and create buy-in from all stakeholders, increasing the chance that the strategy will remain viable over the lifetime of lunar exploration.

**Private sector** – As national space agencies push cutting-edge exploration outward, the private sector should become increasingly involved beyond low earth orbit. To ensure that the outcomes of publicly funded activities can feed toward the future economic development of space, ideas from the private sector should be considered as early as possible.

**International space agencies and emerging space-faring nations** – We commend NASA on involving 13 other space agencies in strategy development thus far. We note, however, that restrictive trade regulations have to an extent hindered involvement by representatives from a broader cross-section of nations. We implore decision makers to resolve these issues to promote a more fertile exchange of ideas. In addition, we recommend increasing the involvement of emerging space-faring nations, perhaps in mentor-protégé relationships.

**Military** – Objectives such as security and state-of-the-art defense technology go hand in hand with such a lunar exploration initiative. Where realistic, we recommend inclusion of military leaders and strategists.

**Academia** – Academic researchers can provide a unique perspective on the long-term future. A neutral outlook, not based on politics or profits, can focus on basic science and exploration. Support for academia is needed to advance knowledge in these areas and train future generations.

**General Public** – The general public will need to support exploration for it to be sustainable in the long term. In particular, today's students will be integral to implement the strategy because they will sustain the space sector workforce. To ensure the support of current and future generations, the public must become actual stakeholders, not just receivers of one-way communications about space activities. We recommend a proactive and interactive approach to engaging the public, utilizing participatory forums such as citizen juries and consensus conferences.

In addition to including all of the above stakeholders in the strategy development process from its initial phase, we stress the importance to keep and ongoing development and assessment of the lunar exploration strategy. We recommend the implementation of a structured feedback loop to encourage accountability and follow-through. Not all suggestions need to be accepted; however it is important to make sure contributors know their inputs have been considered.

## **Define a Rationale for Exploration**

While we recognize the value of the core and crosscutting themes outlined in the Global Lunar Exploration Strategy, we found that questions pertaining to the purpose of space exploration were left unanswered. In this age and political climate, we feel that there is no clear reasoned rationale being discussed, and thus the public is left to conjecture rationale for public spending on space exploration.

In response to this uncertainty, we recommend that the exploration strategy more deeply examine the fundamental rationale for engaging in space exploration and express it at a higher level than what is currently addressed by the lunar exploration themes. The rationale should be meaningful to the general public and answer the questions: Why explore? Why extend human settlement to space? Why do these things as a global community? This rationale should not be specific to lunar activities, but to all exploration.

While we did not have time at the NGEC to develop this rationale fully, we would like to suggest that exploration satisfies needs more fundamental to humanity than those described in the current themes. It is not the carrying out of a vision directed by a governing entity, nor the capitalization of an economic opportunity, but human nature itself that will ultimately propel our species to extend its presence in the universe. Our exploratory nature, our need for survival, our search for life beyond our own, and our endless pursuit of peace on Earth make up a core motivational platform upon which the rationale for exploration objectives can be built.

**Exploratory Nature** – There is no shortage of historical examples to demonstrate the existence and importance of the human instinct to explore. This innate human presence has driven us toward global settlement and the eventual extension of civilization to other worlds.

**Survival Instinct** – While the meaning of our existence in the universe is debated, the need to protect it is not. As long as humans remain confined to a single planet, there is a possibility that a catastrophic event could end civilization. Such events include a global disease pandemic, asteroid or comet impact, and nuclear war, among others. Extending human civilization to space could enable our species to avoid extinction after such a devastation.

**Search for Life** – Humanity has long asked the question, “Are we alone?” We seek an understanding of our own existence and our place in the universe. Space exploration offers the opportunity to shed light on these topics through the search for evidence of life elsewhere in the universe. If life exists beyond the Earth, not only will that discovery shake the foundations of our worldview, but finding life that originated from a second genesis would give us a separate biological system to compare to our own. With this important second data point, we could learn how life works on a more fundamental level and contribute to our understanding of how to protect and enhance our existence.

**World Peace** – A benefit of space exploration can be the unification of humanity under one banner. As we journey further from Earth, we will lose our national identities and become representatives of all humankind. As many fortunate astronauts have observed, the view of Earth from space is without borders. While enhancing global partnerships is currently a “crosscutting theme” in the Global Exploration Strategy, we recommend elevating it to the level of an overarching rationale. Engaging the world community in the peaceful pursuit of common objectives should be a primary motivator for and benefit of cooperative space exploration.



### Engage the Next Generation

The participants of the NGEN were pleased with the opportunity to comment on the Global Lunar Exploration Strategy. As members of the community tasked with performing the daily work of today's exploration, we welcomed the opportunity to look beyond and anticipate the future direction of exploration.

We do not believe, however, that involvement of the "next generation" should begin and end with the NGEN or even the development of the exploration strategy. While, as the "next generation," we are currently in the early stages of our careers, as time progresses we will become the leaders for missions to the Moon, Mars, and beyond. In order for the next generation to be most effective in executing the global strategy, we must be involved in its creation and development. Again, we commend NASA for soliciting our input at the NGEN, but stress that our participation must be maintained beyond this single event.

To engage the space professionals of our generation, we propose the establishment of a Next Generation Exploration Analysis and Engagement Group. This group should establish a standing relationship with NASA and other space agencies and institutions, to provide input to future exploration strategy and activities, while serving as a conduit for engagement with the next generation. A group comprised of those at the NGEN, along with "next generation" representatives from the stakeholder communities discussed above, would be both representative of the global space community and a unique voice within it.



# **Agenda** from the **Next Generation Exploration Conference**

## Tuesday, August 15, 2006

- 12:00-13:00 **Tour and Advanced Registration**—Badging Office  
- Attendees who have signed up for the tour and submitted paperwork meet in the Main Badging Office to check-in for the conference and the tour
- 12:30-16:00 **Tour of NASA Ames Research Center**
- 18:30 **Informal Discussion and Dinner**—NASA Lodge picnic area  
o “The Future of NASA’s Workforce”  
*Garth Henning, NASA Headquarters*

## Wednesday, August 16, 2006

- 08:00-09:00 **Registration**—Building 3 Lobby  
*Continental Breakfast*
- 09:00-12:00 **Plenary 1: Welcome and Background**—Ballroom  
09:00 o Welcome  
*Kennda Lynch, Master of Ceremonies*  
09:15 o “Dawn of a New Space Age: Developing a Global Exploration Strategy”  
*Jeff Volosin, NASA Exploration Systems Mission Directorate*  
10:00 o “Towards the Establishment of a Strategic Framework for a Global Exploration Strategy”  
*Piero Messina, European Space Agency*  
10:45 o “Till the Ductile Anchor Hold: Towards Space Settlements in the 21st Century”  
*Jim Dator, University of Hawaii*  
11:30 o Overview of the Conference  
*Kennda Lynch*
- 12:00-12:15 **Group Photo**
- 12:15-13:15 **Lunch** – Ballroom  
o “Introduction to Ames”  
*Jack Boyd, NASA Ames Research Center*
- 13:30-15:30 **Working Group Session 1: Lunar Exploration Themes and Objectives**  
—Working Group rooms  
- Introduction of team members  
- Teams will become familiar with online collaboration technology  
- Teams will review and comment on the themes and objectives for lunar exploration from the NASA Synthesis Team (Global Exploration Strategy)
- 15:30-16:00 **Break**

16:00-18:00      **Working Group Session 2: Lunar Exploration Themes and Objectives (continued)**—Working Group rooms  
 - Teams to comment on lunar exploration themes and objectives and summarize their findings into a report

18:00              *Adjourn for the day*

## Thursday, August 17, 2006

08:00-09:00      **Science Presentations within the Working Groups**—  
 Working Group rooms  
*Continental Breakfast*

- o Asteroids  
*Dr. John Lewis, University of Arizona*
- o Cis-lunar  
*Dr. Bryan Laubscher, Los Alamos National Laboratory*
- o Earth 3.0  
*Dr. James Dator, University of Hawaii*
- o Mars Science and Exploration  
*Dr. David Beaty, NASA Jet Propulsion Laboratory*
- o Mars Settlement and Society  
*Dr. Chris McKay, NASA Ames Research Center*
- o Virtual Exploration and Virtual Worlds  
*Claudia L'Amoreaux, Linden Lab*

09:00-10:00      **Working Group Session 3: Themes and Objectives for 'Beyond'**—  
 Working Group rooms  
 - Teams to create exploration themes and objectives for their destination

10:00-10:30      *Break*

10:30-12:00      **Working Group Session 4: Themes and Objectives for 'Beyond' (continued)**—Working Group rooms

12:00-13:00      *Lunch* –Ballroom  
 o "Navigating the Politics of Science & Exploration"  
*Matt Lacey, NASA Kennedy Space Center*

13:00-15:30      **Working Group Session 5: Themes and Objectives for 'Beyond' (continued)**—Working Group rooms

15:30-16:00      *Break*

16:00-18:00      **Working Group Session 6: Themes and Objectives for 'Beyond' (continued)**—Working Group rooms

18:00              *Adjourn for the day*

## Friday, August 18, 2006

- 08:00                    **Working Group Session 7**—Working Group rooms  
*Continental Breakfast*
- 10:00-11:00           **10 Minute Presentations by each group**  
- One slide on high level lunar discussions, rest on themes, objectives, issues/  
  enablers, actions for each group
- 11:00-12:00           **Roundtable Discussion**—Ballroom  
- Each presenter will sit up front, and there will be an hour of question/  
  answer time.
- 12:00-13:00           *Buffet Lunch*—Ballroom  
    o "The Next Generation of NASA"  
      *S. Pete Worden, Center Director, NASA Ames Research Center*
- 13:00-14:30           **Working Group Session 8: Final Reports**—Working Group rooms  
- Declaration – This working group will compile the recommendations from  
  each of the earlier working groups into a single official NGEC Declaration.  
  Two new working groups, 1. NGEC declaration and 2. NGEC response to the  
  Lunar portion of the Global Exploration Strategy.
- 14:30-15:00           **Final Words, Wrap-up**—Ballroom
- 15:00-15:30           *Free*
- 15:30-17:30           **Cooper Winery Tour**  
- Meet in parking lot of Building 3 and ride share to winery.

# **Speakers Presentations to the Next Generation Exploration Conference**



**Jeff Volosin**

NASA Exploration Systems Mission Directorate

Jeff Volosin is an aerospace engineer with over 20 years of experience in the design, development, and operations of both robotic and crewed spacecraft. Mr. Volosin is currently leading the NASA effort to develop and integrate a global exploration strategy which reflects the lunar exploration interests of international space agencies, academia and commercial stakeholders. Prior to joining NASA as a member of the Exploration Systems Mission Directorate in 2004, Jeff was an aerospace contractor, serving in a number of leadership positions including: Operations Manager for the NASA Communications Network and Flight Operations Manager for the Advanced Composition Explorer, Tropical Rainfall Measuring Mission, and the NOAA Polar and Geostationary satellite constellations. Earlier in his career, Jeff spent 4 years as a system engineer supporting the Space Exploration Initiative studies on human voyages to the Moon and Mars and also supported the Space Station program as an advanced life support engineer.





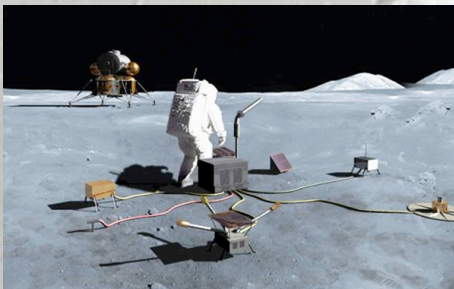
## ***Dawn of a New Space Age: Developing a Global Exploration Strategy***

**Jeff Volosin**  
**Strategy Development Lead**  
**NASA Exploration Systems Mission Directorate**  
**August 16, 2006**



## ***A Bold Vision for Space Exploration, Authorized by Congress***

- ◆ Complete the International Space Station
- ◆ Safely fly the Space Shuttle until 2010
- ◆ Develop and fly the Crew Exploration Vehicle no later than 2014 (goal of 2012)
- ◆ Return to the Moon no later than 2020
- ◆ Extend human presence across the solar system and beyond
- ◆ Implement a sustained and affordable human and robotic program
- ◆ Develop supporting innovative technologies, knowledge, and infrastructures
- ◆ Promote international and commercial participation in exploration



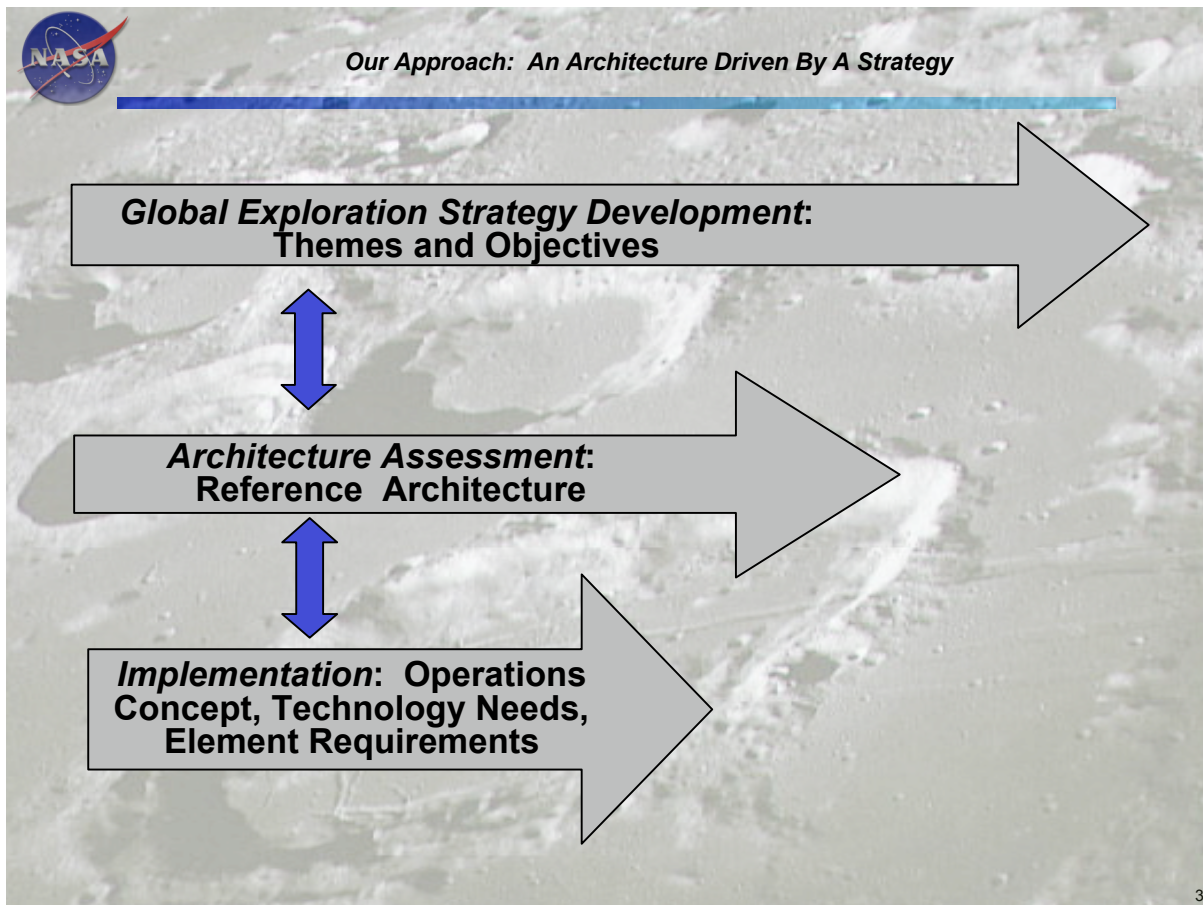
### **NASA Authorization Act of 2005**

*"It is time for America to take the next steps."*

The Administrator shall establish a program to develop a sustained human presence on the Moon, including a robust precursor program to promote exploration, science, commerce and U.S. preeminence in space, and as a stepping stone to future exploration of Mars and other destinations.

*President George W. Bush –  
 January 14, 2004*





3

**What is a 'Global Exploration Strategy'?**

- ◆ **The compelling answer to the following questions:**
  - “Why” we are going back to the moon and
  - “What” we hope to accomplish when we get there
- ◆ **Not a definition of ‘how’ we will explore (operations & architecture)**
- ◆ **Global - refers to the inclusion of all stakeholders in the strategy development process - to ensure that as NASA moves forward in planning for future exploration missions - we understand the interests of:**
  - International Space Agencies
  - Academia
  - Commercial Investors
- ◆ **Includes the moon, Mars, and beyond as potential destination for exploration:**
  - Initially focused on human and robotic exploration of the moon
  - An evolving plan that will expand to include Mars and other destinations

4





## ***What is a 'Global Exploration Strategy'?***

- ◆ **A blueprint of exploration objectives that will serve as a starting point for:**
  - **Collaboration:** discussions between participants regarding areas of potential collaboration
  - **Coordination:** coordination among participants to maximize what can be accomplished
  - **Mission Design:** detailed technical analyses that address,
    - ***Time Phasing*** of activities and identification of dependencies between objectives
    - ***Prioritization*** based on inputs from various stakeholders
    - ***Operational and Architecture Impacts*** of implementation of the strategy

5



## ***Components of Exploration Strategy***

- ◆ **Themes:** Address the question: **Why should we return to the moon?**
- ◆ **Objectives:** Address the question: **What are we going to do when we get there?**

6





## *Components of Exploration Strategy*

### ◆ Themes

- Provide the high level rationale for exploring the Moon
- Provide a framework for capturing the many objectives across multiple disciplines
- Divided into two types – **core** and **crosscutting**
  - **Core** themes address the primary reasons for conducting activities on the Moon
  - **Crosscutting** themes address ways to maximize the benefit of the core themes

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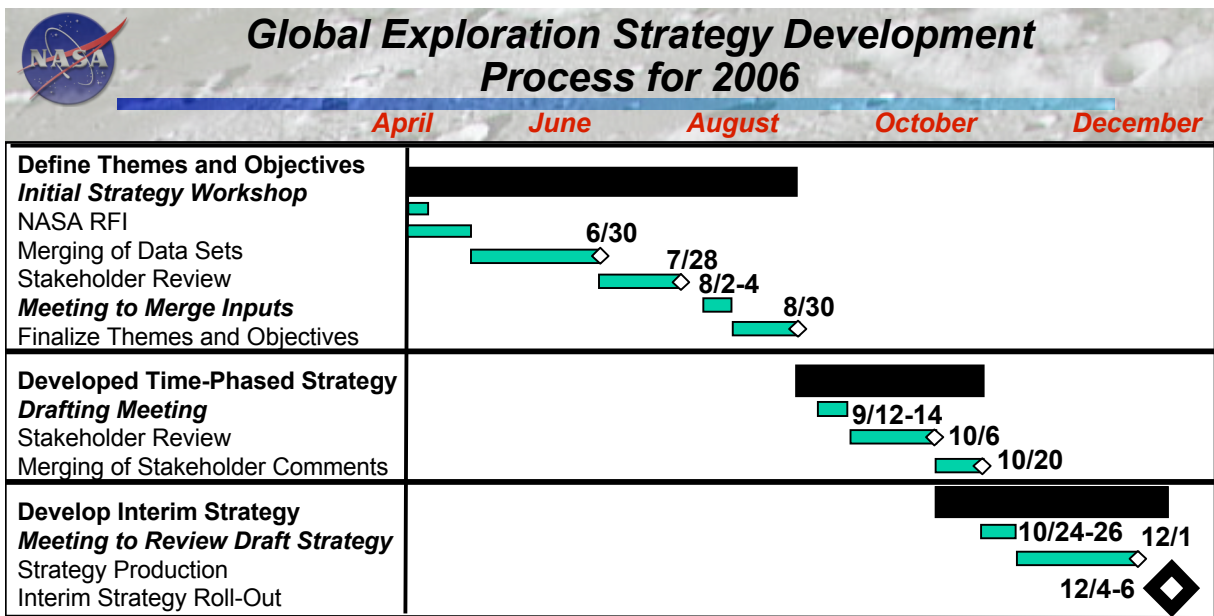
## *Components of Exploration Strategy*

### ◆ Objectives

- Describe the discrete set of activities that the global community has defined as important in supporting the exploration themes
- For example, the theme of using lunar exploration to prepare for future human missions to more distant destinations can be described by a set of associated objectives, such as scientific measurements, mission simulations, and technology and operations validation.
- Serve as a means for breaking down the theme areas into achievable parcels of work that can be time-phased and prioritized – while still being at a strategic level

8





### 2006 Products

- NASA developed video and brochure that address the two basic questions - "Why" and "What"
- Internationally developed "*Strategic Framework for Sustainable Global Space Exploration*" to establish a framework for future coordination and collaboration

**Current Draft: Overarching Themes**

**The following three Core Themes** address the primary activities to be conducted on the Moon:

- ◆ Use the Moon to prepare for future human and robotic missions to Mars and other destinations
- ◆ Pursue scientific activities to address fundamental questions about the solar system, the universe, and our place in them
- ◆ Extend sustained human presence to the Moon to enable eventual settlement





## Current Draft: Overarching Themes

**The following three Crosscutting Themes** address ways to maximize the benefit of the core themes:

- ◆ Expand Earth's economic sphere to encompass the Moon and pursue lunar activities with direct benefits to life on Earth
- ◆ Strengthen existing and create new global partnerships
- ◆ Engage, inspire, and educate the public

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## Current Draft Exploration Strategy Objectives

Objectives collected from the workshop and RFI were grouped into 23 categories:

- |                                    |  |
|------------------------------------|--|
| 1. Astronomy & Astrophysics        | 13. Surface Mobility                     |
| 2. Earth Observation               | 14. Transportation                       |
| 3. Geology                         | 15. Operational Environmental Monitoring |
| 4. Materials Science               | 16. General Infrastructure               |
| 5. Human Health                    | 17. Operations Test & Verification       |
| 6. Environmental Characterization  | 18. Lunar Resource Utilization           |
| 7. Operational Support             | 19. Historic Preservation                |
| 8. Life Support & Habitat          | 20. Development of Lunar Commerce        |
| 9. Environmental Hazard Mitigation | 21. Global Partnership                   |
| 10. Power                          | 22. Public Engagement                    |
| 11. Communication                  | 23. Program Execution                    |
| 12. Guidance, Navigation & Control |  |

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## **Current Draft Exploration Strategy Objectives (Example)**

### **Geology**

- ◆ **Objective: Determine the diversity of crustal rocks to better understand planetary differentiation processes**
  - **Value: The Moon presents the best opportunity to geochemically characterize early fundamental processes of a planetary body of substantial size. Much of the first billion years of planetary geochemical evolution is not available on Earth. In this regard the Moon and Earth represent end-member bodies in that the Moon reveals early geochemical processes, whereas the Earth is a continually active planet. Mars probably represents an intermediate case**

13

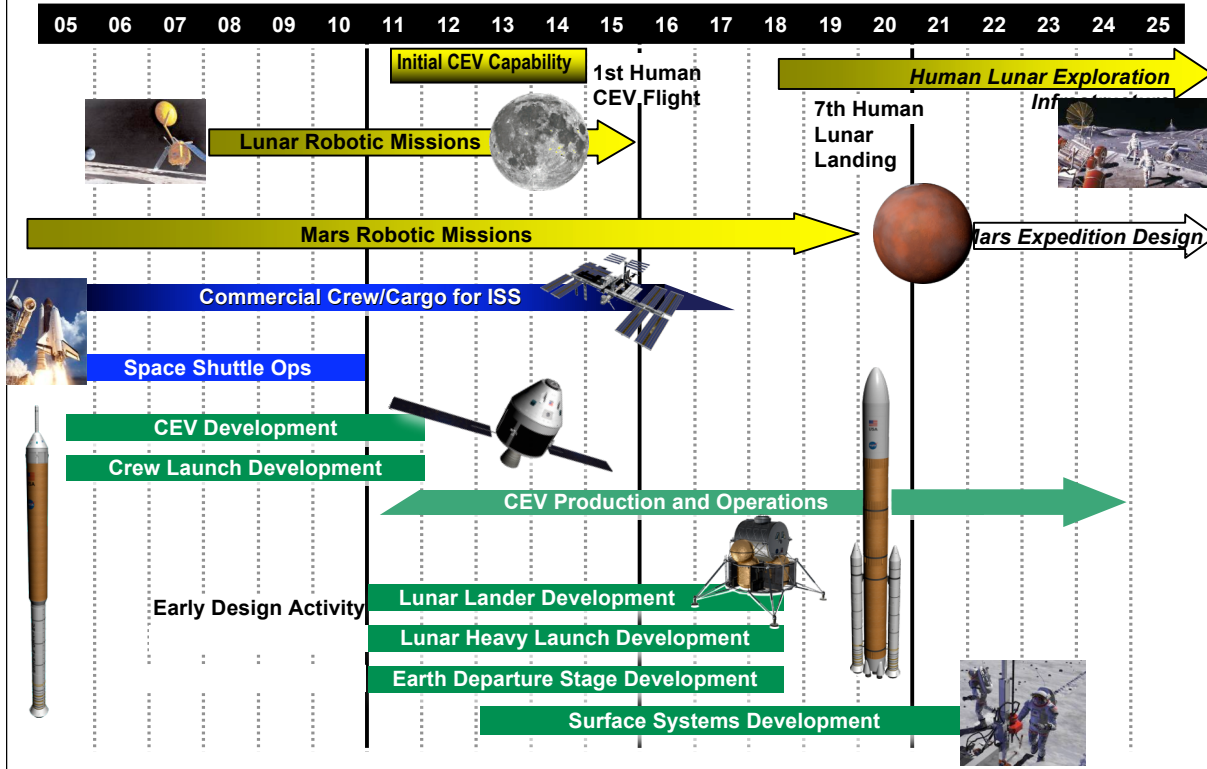


## **Using Strategy to Drive Architecture Design: NASA's Lunar Architecture Study**

- ◆ **Study Objectives**
  - **Define a series of lunar missions constituting NASA's lunar campaign to fulfill the Lunar Exploration elements of the Vision for Space Exploration**
    - Multiple human and robotic missions
  - **Develop process for future Architecture updates**
  - **Drive architecture studies from exploration strategy objectives**
- ◆ **Two Phase Process**
  - **Phase I (Initial Internal NASA Studies)**
    - **Understand architecture and operational impacts associated with the implementation of the key objectives that NASA is interested in achieving based on the Vision**
  - **Phase II (Maturation and Discussion With International Space Agencies)**
    - **Provide sufficient definition and supporting rationale for near term missions to enable commitment to these missions**
    - **Define areas of potential coordination and collaboration**

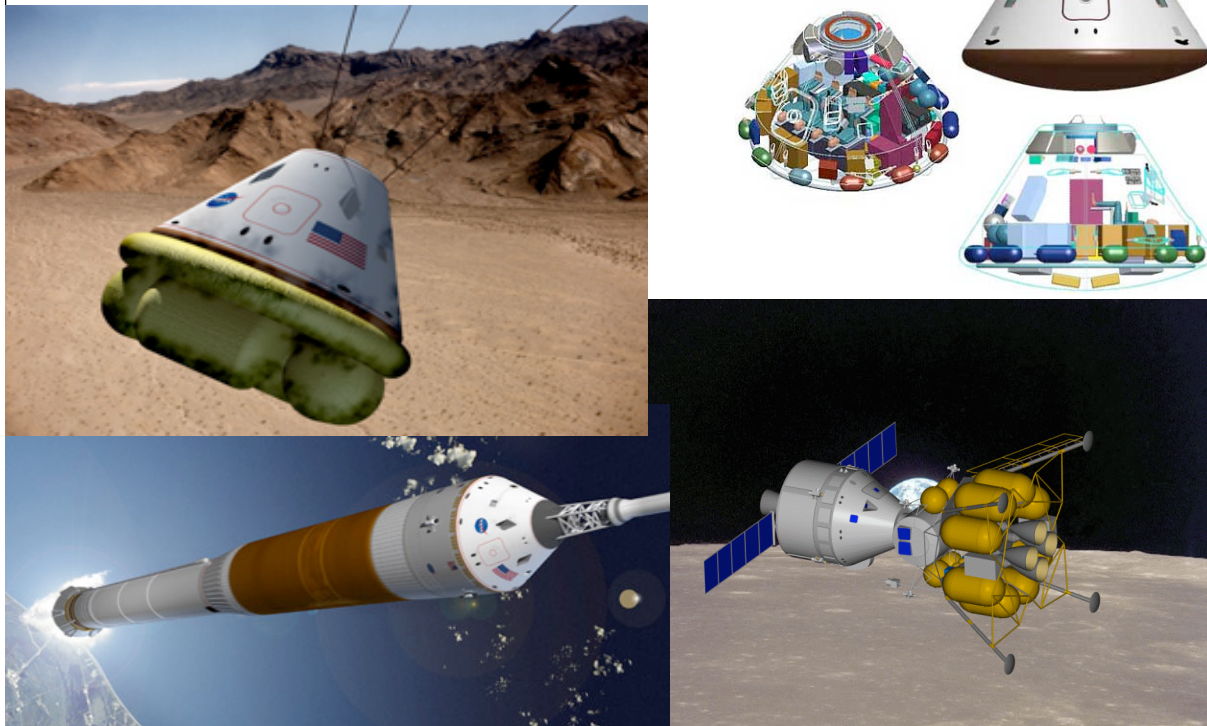
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## Using an Overarching Architecture to Drive Element/Operations Requirements



## Looking Beyond the Shuttle - Focus on Ensuring Crew Safety During Transition In/Out of Earth's Atmosphere

Crew Exploration Vehicle (CEV)







## Designing Launch Vehicles for the Long-Haul

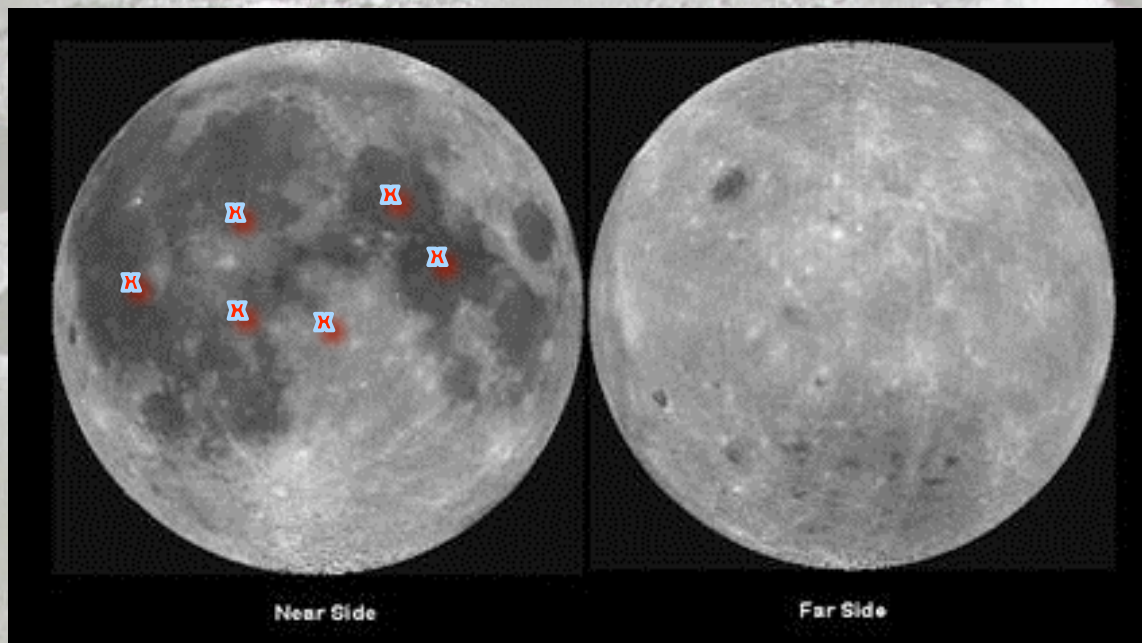


- **Near-Term: ISS Support**
- **Long-Term: Human Moon & Mars Exploration Support**

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## Where Will We Go When We Return? Many Exciting Places Remain to Visit



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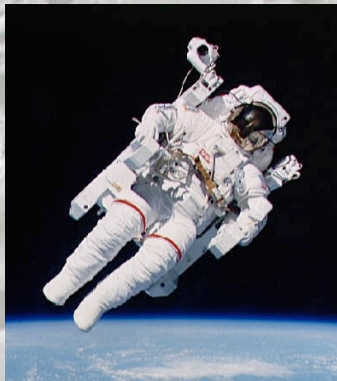
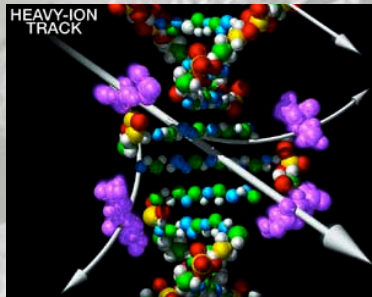




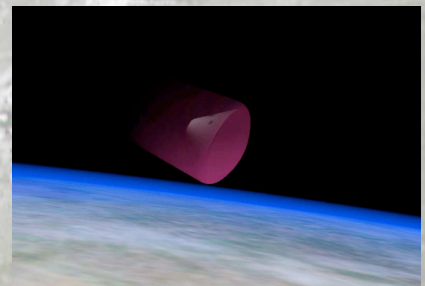
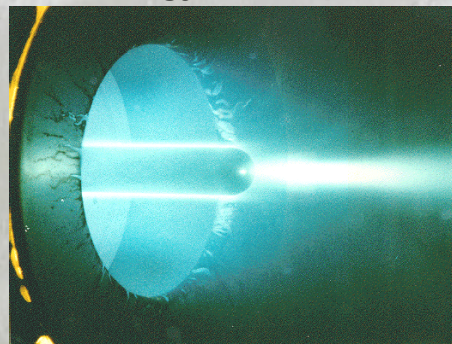


## Building the Future Will Involve More Than Just Exploring The Lunar Surface

### Human Research



### Technology Development



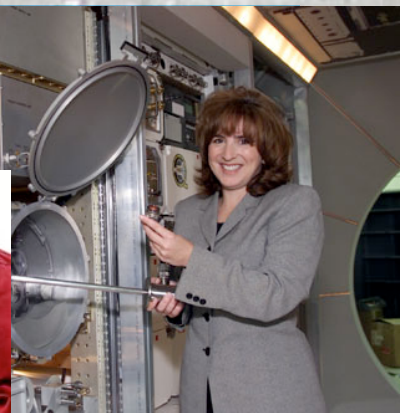
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## Why Do We Explore Space?

To Benefit Mankind Through

- ◆ Discovery
- ◆ Invention
- ◆ Expansion of Our Horizons
- ◆ Inspiration







**Piero Messina**  
European Space Agency



Piero Messina, of Italian nationality, has been working on the ESA's space exploration programme Aurora since its inception also acting as Secretary of the supervisory Board of Participants. He is currently dealing with coordination and public affairs for the Programme Aurora. In this capacity he has been deeply involved in the on going talks with international partners on a global strategy and international cooperation for space exploration. He is the organiser of the series of the joint ESA / ASI Spineto workshops. He joined the European Space Agency in 1991 where he held several positions in the field of financial and project management. He served as Coordinator with the Director of Industrial Matters and Technology Programmes. He was responsible for education policies and relations with European Higher Education Institutions until 2003. He holds a degree in Political Science, International Economic Relations, from the University of Florence and a Master in Space Studies (MSS) from the International Space University in Strasbourg.





Towards the Establishment of a Strategic  
Framework  
for a  
Global Exploration Strategy

A view from Europe

*Next Generation Exploration  
Conference - NGECC  
NASA Ames Research  
Center*

August 16, 2006

[piero.messina@esa.int](mailto:piero.messina@esa.int)



Europe's involvement in space  
exploration

Automatic missions to distant Worlds:

Mars Express

Cassini/Huygens (with NASA and ASI)

SMART-1

Venus Express

Participation in the ISS and Human  
Spaceflight

Columbus Laboratory

ATV

European Astronauts

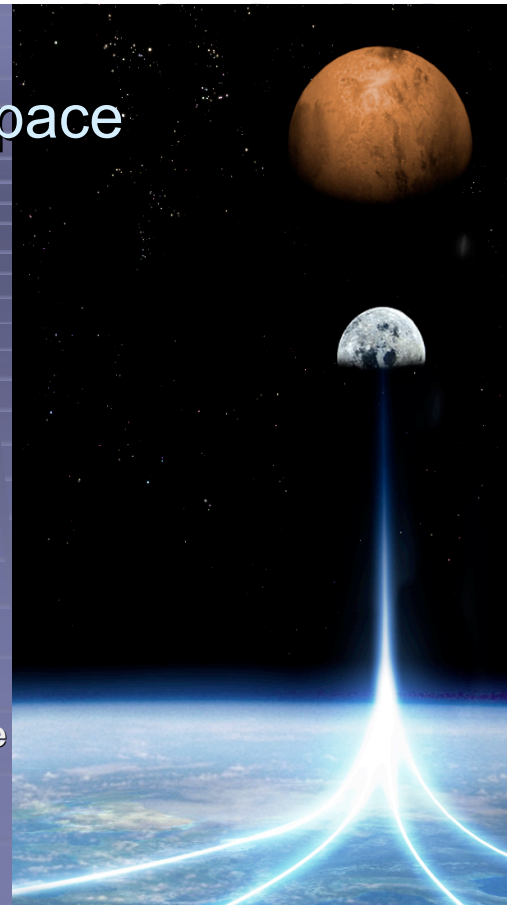
Future exploration activities by Europe  
will build up on the results achieved, the  
investments made and the capabilities  
developed so far



## A renewed spirit for space exploration

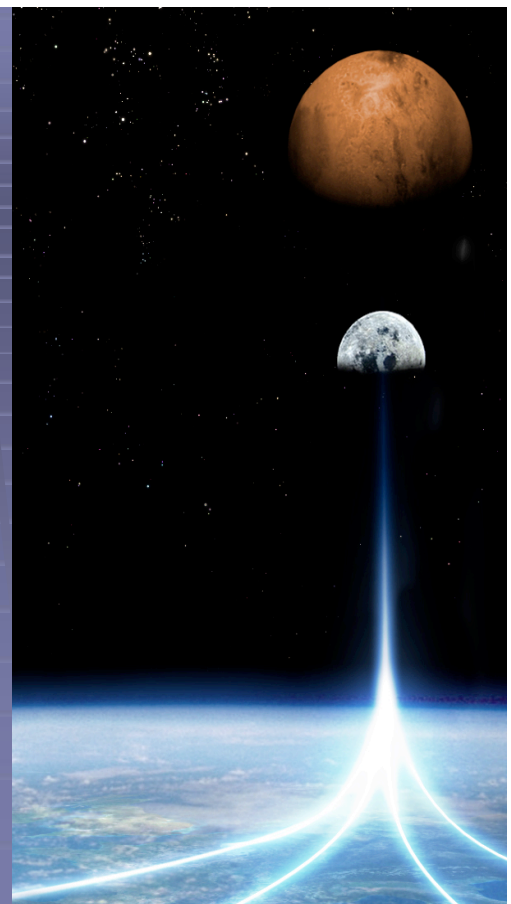
Since few years space exploration has risen on space fairing Nations' agenda:

- ESA's Aurora Programme (2001)
- US President Vision for Space Exploration (2004)
- New JAXA's Vision "JAXA 2025" (2005)
- China manned space programme as well as planned robotic missions to the Moon (Chang'e -1, -2, -3)
- Russia revamped space program include a new crew transportation system as well as robotic missions to Moon and Mars'



## Different Programs – Similar Goals

- Moon is the next immediate target in most cases and is an element of all strategies;
- Mars remains an important destination on long-term and with a strong scientific case;
- Several robotic missions will reach the Moon and Mars in the next 10-15 years;
- First human landings, on the Moon, not likely to happen before 15 years.





## Different Programs – Similar Goals

Declared rationale for space exploration:

- Advancing scientific knowledge;
- Further economic interests (mainly through innovation and support to industrial competitiveness);
- Inspiring the public and the youth in particular;

US Vision specifically calls for advancing:  
“U.S. (...) security interests”.



## International Cooperation

In this seemingly converging context (“a journey not a race”) international cooperation becomes an important enabling element .

It allows to enhance program's robustness

- Strengthen the program domestically;
- Resilience to changing political environment;
- Division of labour as well as redundancy;

- Additional/Gap filling capabilities;  
- Providing leadership.



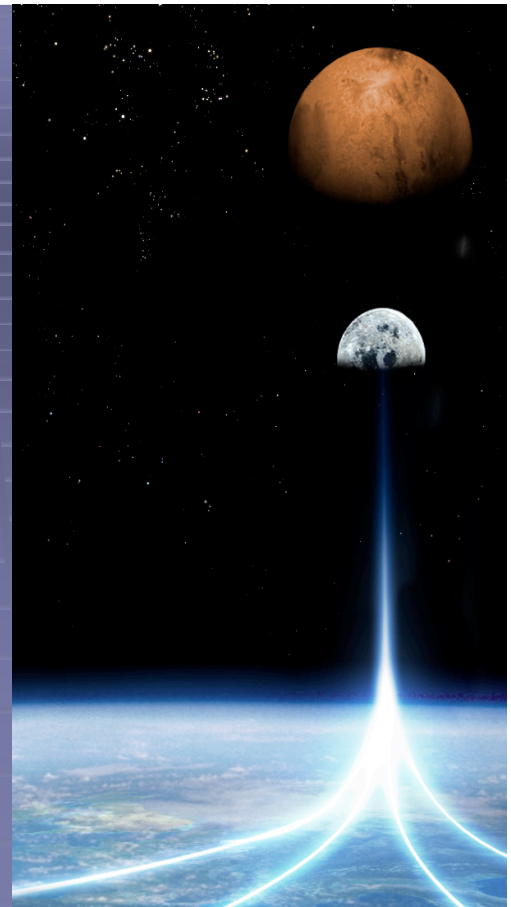
# International Cooperation

All space exploration programs foresee to some extent international cooperation as an important feature. For instance:

*A Renewed Spirit of Discovery (US, 2004):*

*“Promote international and commercial participation in exploration to further U.S. scientific, security, and economic interests”*

ESA's Aurora Program is conceived to prepare Europe to play a significant role in a global space exploration endeavour.



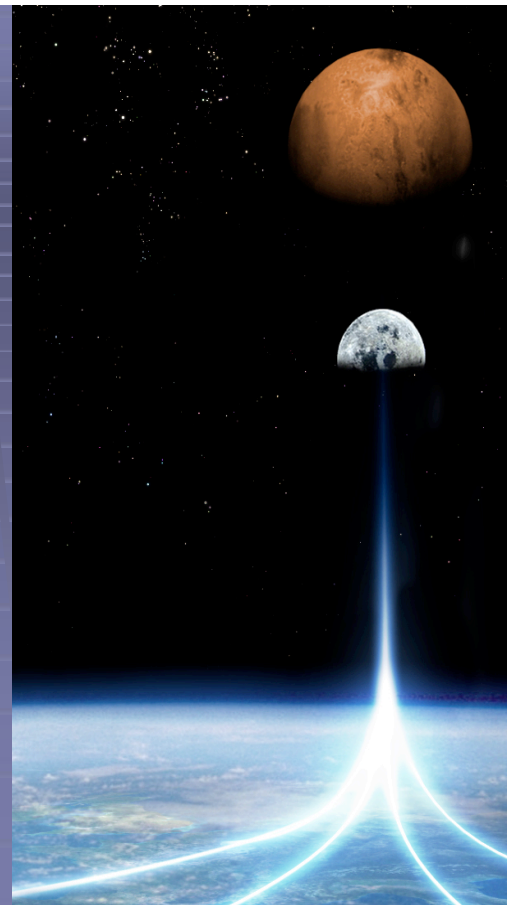
## Establishing an International Cooperation Framework

First consultation of international partners by NASA in November 2004:

First Agency-to-Agency formal talk since the Vision has been announced

Previous NASA Leadership

25 Agencies invited of which 18 attended the event including ESA, EC, JAXA, Roskosmos, CNSA, ISRO, 4 main European national agencies etc.;



## Establishing an International Cooperation Framework

The joint ESA/ASI Workshops on “International Cooperation for Sustainable Space Exploration” in Spineto, Italy:

- 1<sup>st</sup> May 2005
- 2<sup>nd</sup> May 2006

Attempt to create the conditions for a global partnership for space exploration while recognising current NASA's leadership.

Core participation as in previous Workshop in USA



## Establishing an International Cooperation Framework

The currently on going NASA-led process was kicked off in April 2004 with a “non attribution basis” consultation.

A broad Request For Information was launched along with a consultation with stakeholders.

Consultation with 13 International Space Agencies is also part of the process:

- |            |        |         |
|------------|--------|---------|
| - CNSA     | - KARI | - CSIRO |
| - Roscomos | - CSA  | - ISRO  |
| - Jaxa     | - NSAU | - DLR   |
| - ESA      | - ASI  |         |
|            | - BNSC |         |
|            | - CNES |         |

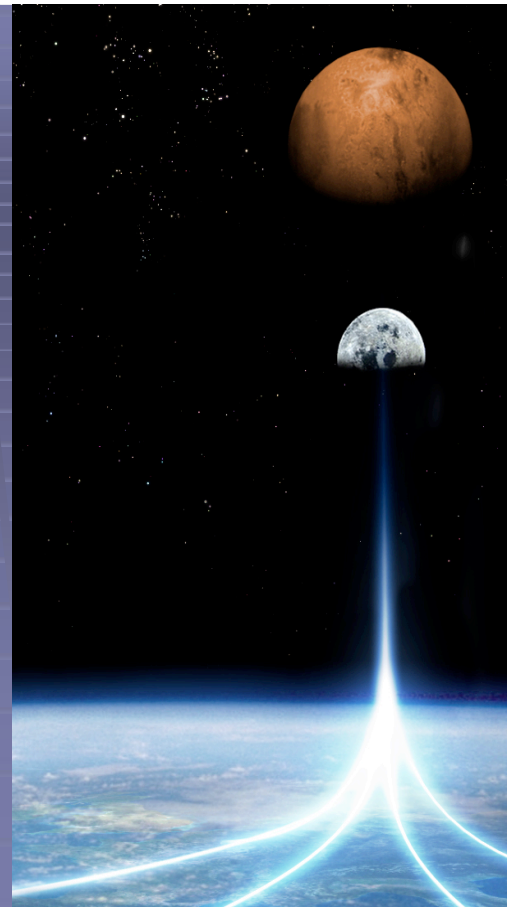


## Establishing an International Cooperation Framework

Collective work among representatives of the space agencies involved will continue intensively over the next months in order to develop a:

**“Strategic Framework for Global Sustainable Space Exploration”**  
(working title)

While continue working under NASA leadership to define a comprehensive set of objectives for Moon exploration (“Why? What?”)

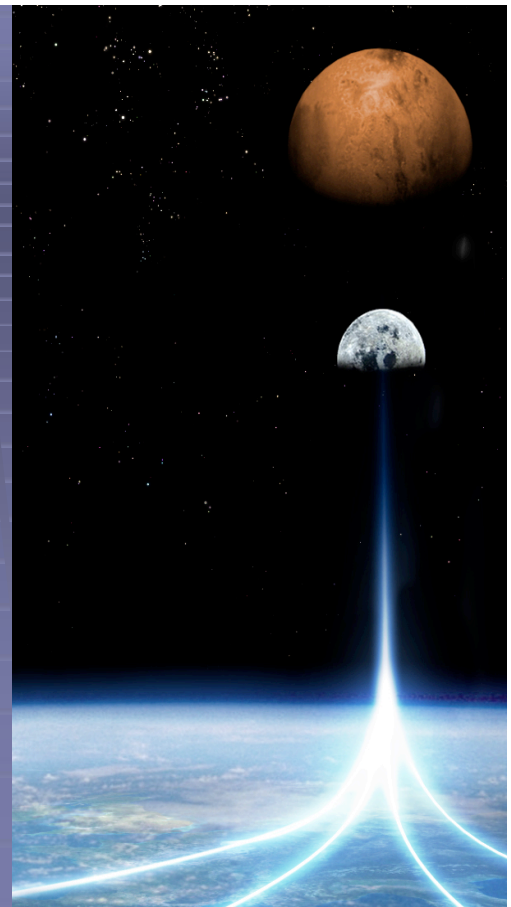


## Establishing an International Cooperation Framework

The International Partners are working towards a shared vision for robotic and human exploration of the Solar System eventually leading to sustained human presence on other Planets.

They will address:

- The global benefits of exploring together;
- The overall exploration goals and the place of Lunar exploration therein;
- The implementation aspects of this global strategy and their desired features.

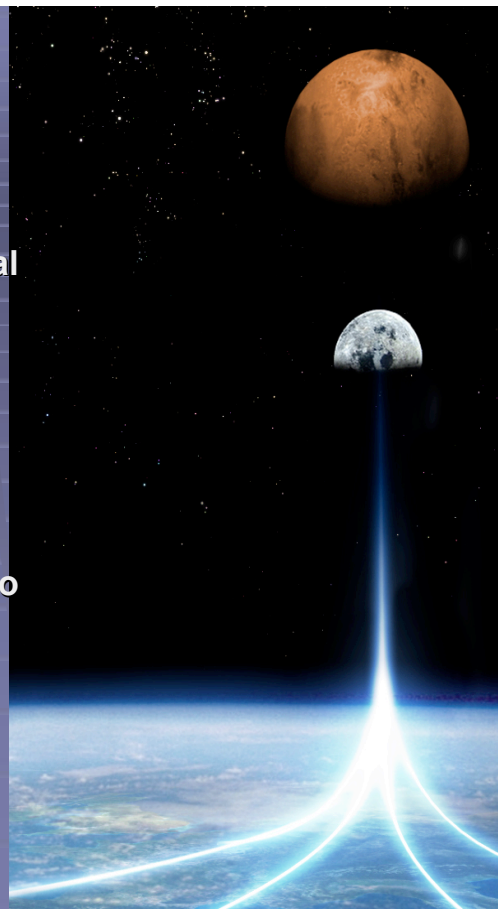




## Establishing an International Cooperation Framework

As a result of the work among international Partners (Montreal mtg.) the proposed Themes were re-worked as follows (not final):

- Serve public policies by inspiring and educating individuals, improving global welfare and sustaining economic growth;
- Foster the development of new markets and technological innovations as well as to demonstrate economic resource exploitation;
- Strengthening and expanding global partnerships among nations;
- Pursue scientific activities to address fundamental questions about the solar system, the universe, and our place in



## Conclusions

Europe, through ESA in coordination with its Member States, is committed to Space Exploration in the frame of a balanced European Space Policy.

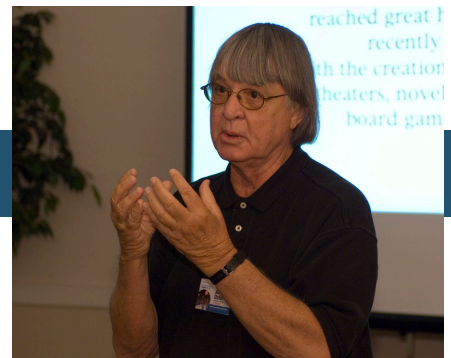
Space Exploration is envisioned as a global undertaking involving as many nations as possible.

International cooperation is a condition to ensure robustness and long term sustainability of space exploration

Consultation and coordination is a key feature that should not prevent however each partner to retain control of its program.



**Jim Dator**  
University of Hawaii



Jim Dator is Professor and Director of the Hawaii Research Center for Futures Studies, Department of Political Science and Adjunct Professor in the Program in Public Administration, the College of Architecture, and the Center for Japanese Studies, of the University of Hawaii at Manoa; Co-Chair, Space and Society Division, International Space University, Strasbourg, France; former President, World Futures Studies Federation; and Fellow and member of the Executive Council, World Academy of Art and Science. He also taught at Rikkyo University (Tokyo) for six years, the University of Maryland, Virginia Tech, the University of Toronto, and the InterUniversity Consortium for Postgraduate Studies in Dubrovnik, Yugoslavia. He is a Danforth Fellow, Woodrow Wilson Fellow, and Fulbright Fellow. He consults widely on futures of law, governance, education, and space.





**Till the Ductile Anchor hold:  
Towards space settlements in the 21st Century**

Jim Dator  
Hawaii Research Center for Futures Studies  
Department of Political Science  
University of Hawaii

*<dator@hawaii.edu>  
<www.futures.hawaii.edu>*

Humans are restless explorers. For 99% of humanity's time on Earth, we have been nomadic wanderers, not farmers, warriors, factory workers, developers, or NASA employees.

Only recently--for only a few thousand years--have most humans been tied to the land as many are now. But as more and more of us live in information societies and some indeed in dream societies where our identity derives from the knowledge we share and the image we project, and not from the property we own or the manual work we do, the time may be coming when we should break free from the land, and roam once again.

But beware: the reality of Man and Woman the Explorer has a very dark side as well. Many people where I live view the recent experience of Man on the Move as a history of theft, murder, racism, exploitation, and genocide.

So we need to be very careful if we say that space exploration is only natural for humans, since the experience has not been very uplifting and noble for most recipients of the exploring of others.

But such warnings are not new. Humans have been alerting each other to the dangers of change and novelty from the very beginning:

Who and what is this?



Yes, Icarus. Icarus who, with his father, Daedalus, fashioned themselves wings so that they could fly like the birds, something they were totally unable to do with their wingless, flightless natural bodies. So they first imagined flight, and then developed the technologies that would enable it. As you know, Icarus also received a warning from his father before he took off:

According to Ovid, Daedalus said:

*"My Icarus, I vow thee fly  
Always the middle track; nor low, nor high;  
If low, thy plumes may flag with ocean's spray  
If high, the sun may dart his fiery ray."*

So there you have one of the very first examples of a technology risk assessment.

But Icarus, being a typical son--and a typical human--disregarded his father's warning. He did fly. But then he sailed too close to the sun which melted the wax on his wings and cast Icarus to his death in the ocean below.

The daring and hubris of Icarus has been a very popular theme in Western art and literature, warning us of the eternal tension between what we want to do and then can do because we develop *technological* capabilities, on the one hand, in contrast with what we ought to do, given our *ethical* limitations and frailties, on the other.

There have been scores of paintings about Icarus from early Greece down to 20th century artists. Without a doubt the most famous painting about the Fall of Icarus was by Pieter Bruegel (or one of his sons). I am sure you have seen it:



But wait. Is this a picture of the fall of Icarus, or about early contour plowing and sheepherding. Where is Icarus in this painting?

That is what makes it such a great work of art. Icarus is barely visible. This whole great human tragedy just doesn't seem to matter at all.

But there he is--down in the right hand corner of the picture--only his feet and legs showing as he splashes into the briny deep. Puny humans defeated by preening pride and technological over-reach.

This painting has inspired scores of poems as well. Probably the best known in English is by W. H. Auden. But I am going to read one by a much less well-known poet, but a poem I find to be more fitting for a high tech bunch of guys like you. It is by Ronald Bottrall who is a British poet who actually was a contemporary of Auden:

**In his father's face flying  
He soared until the cities of the Aegean  
Opened like blood vessels lying  
Under a microscope. End on  
He saw below the trunks of trees  
While space-time flowered in his sunward eyes.  
His feathered arms, extension  
Of nimble thoughts, pride of invention,  
Were lifting him high above man.  
"And if I fly,"  
He said, "to the source of mortal energy  
I shall capture the receipt  
To administer light and heat."  
But sunlight to all eyes is not bearable  
Or sunheat to all blood.  
His motion turned to Earth, unable  
To sustain its presumptuous mood.  
Falling he saw the cantilevered birds,  
Their great humerus muscles bearing  
Them in their spacious veering  
Over shores and sherds  
Over swords and words.  
Like a detached leaf, feeble  
In the wind, he fell,  
A multitude of molecules  
Organized in equal and parallel  
Velocities (according to the rules  
Of motion) to seek the ground.  
And on the slope above the sea  
The hard-handed peasants go their round  
Turning the soil, blind to the body  
Ambitious and viable, whose pride  
Will leave no trace in the quenching tide.**

So far, I have given only Western examples.

But every culture has its own stories about space flight and exploration. The other culture I know best is Japan, and there are various examples there.

One of the best known stories that came to Japan from China and Korea is currently recalled during the *Tanabata* festival. It is held on the seventh night of the seventh month during the annual meeting of the stars Vega (or *Orihime*, the seamstress, in Japanese) and Altair (or *Hikoboshi*, the Ox-Herder) two stars that, for the rest of the year, are separated by the Milky Way (or *Amanogawa*) and only allowed to be together once a year for a brief time.

The reasons vary as to why the two lovers--and stars--are separated and allowed to meet each other only briefly for once a year, but they are all based on plots that have humans being punished for doing what they *want* to do rather than doing what they know they *ought* to do, very much like Icarus.

Interestingly enough, the Japanese space agency, then known as NASDA, named a pair of Japanese satellites *Orihime* and *Hikoboshi*. The two were launched together as ETS7 (Kiku 7) and separated before coming together again in 1999. It was the first time such docking had ever been done automatically. There were problems with the attitude control system when the maneuver was repeated, but the two star-crossed lover satellites did finally successfully rendezvous again.

One of the oldest and best known Japanese stories is about *Kaguya Hime*, a maiden who it turns out was born on the moon, came to live on Earth for a while, and returned to the moon in splendor.

A final example is the well-known Japanese folk tale about Momotaro--the Peach Boy. It features a baby who is discovered in a huge peach (momo) when it is cut open. The man and his wife nurture the baby to adulthood. Momotaro then rights various wrongs on Earth and eventually sails off to a land far away.

It is a kind of Christ story, or superman story, or as some interpret it now, a story about ET. Or it may just be a story.

There are many more such stories in all cultures. Both the desire to go to space and the dangers implicit in that desire are part of every culture on Earth.

But many things had to happen before that feat became possible. For one thing, more compelling stories, such as those of Jules Verne and H. G. Wells, had to be written showing that, just as humans had discovered unknown worlds on Earth, so now it was possible to imagine and discover--or to create--new worlds in space.

No one was more visionary in that regard than the Russian, Konstantin Tsiolkovsky.

Tsiolkovsky had everything it took to be a visionary: Though born in an obscure part of Russia in 1857, his father was a poor woodcutter from Poland and so Konstantin was not a native Russian. He was deaf. He never went to school and received no formal education at all. Rather, he was tutored privately by the eccentric Russian philosopher Nikolai Fedorov, who himself was a leading proponent of a marginal movement called "Russian Cosmism". Konstantin also read the works of Jules Verne. He lived and worked in Kaluga, far from the sights and influences of modernizing Moscow.

So you can see that he had what you need to be creative--not wealth, a happy, successful family, proper socialization, and graduation from a prestigious school. All of that is a recipe for mediocrity that can make you a successful bureaucrat or even President of the US. But Tsiolokovsky had the Right Stuff needed for genius: he was handicapped, an immigrant, uneducated, and socially isolated.



What could he do but think and dream? And he did both on an unimaginably broad and deep scale. Under the influence of Fedorov, he formulated the “Cosmic Philosophy” which included the belief that

**“Humanity will not remain on the Earth forever, but in the pursuit of *light and space* will at first timidly penetrate beyond the limits of the atmosphere, and then will conquer all the space around the Sun.”**

He also wrote the often-misquoted statement that contains the greatest rationale for space exploration ever expressed:

*“The Earth is the cradle of the mind, but we cannot live forever in a cradle”.*

Tsiolkovsky was certain that it was the destiny of humankind to occupy the solar system and then to expand into the cosmos, living off the energy of the stars to create a cosmic civilization that would modify nature, abolish natural catastrophes, and achieve happiness for all. That was the “Cosmic Philosophy”.

But, even more incredibly, at the same time he was developing these ideas--and writing science fiction stories to support them--he was also coming up with sophisticated and largely accurate drawings and mathematical formula for actually doing what his philosophy required and his fiction explained:

Tsiolkovsky died in 1935 but shortly after it seemed that his dreams would come true.

Once upon a time, in a heroic period called “the 1960s”, humans--true supermen, of course--actually did go to the moon. They also invented Rock and Roll, but that is another story.

I know it is very difficult for some of you to believe any of this since the moon is so far away from any place you can go now. But the story is no hoax. Once upon a time humans did actually walk on the moon. Though impossible now, this is not a myth but a fact.

I think more and more people now understand that our journeys to the moon and plans to go to Mars in the 1960s perhaps were very premature, being weird byproducts of an even weirder political struggle between the US and the USSR. Humanity at that time was testing the limits of its technologies, will, and finances in many ways, but none more spectacularly than by walking on the moon and then returning safely to Earth to tell about it.

But it all turned out to be so daunting and exhausting and expensive that humans have not ventured out of immediate Earth-orbit since, and we may never do so again.

Humans, 100, 500, 10,000 years from now may look back on the Apollo Era as indeed an time of supermen like Icarus and Momotaro who are said to have done impossible and daring things once upon a time, long, long ago, and never again, as our courage failed and as pressing Earthly problems, real or imagined, overwhelmed us.

Now, after four decades of dormancy, the stories about going back to the moon and on to Mars are growing again and are becoming ever more intense everywhere. Can it happen? Will it happen?

Recently, there is a stirring in the space community again. Plans for going to the moon and beyond are being seriously discussed in many parts of the world, including the US. Yet how realistic are any of them? Does the US, most of all, have the money, talent, and will to push outward into space for peaceful purposes again? The current American president seems to think so, but of all of Bush's faith-based initiatives, none seems to me more faith-based than the thought of going back to the moon and on to Mars according to his time table.

But brothers and sisters, I Believe! I have the Faith. Faith is defined as the Triumph of Hope over Reason, and like all of the faithful whatever the object of their faith, I very much want humans to go back to the moon and on to Mars, and to do so very soon.

However, "Civilization," HG Wells once wrote, "is a race between education and disaster" and humanity is presently even more seriously engaged in such a race than when Wells wrote it. One aspect of the race sees humanity wasting its resources and human talent on meaningless wars while the other sees humanity wasting its resources and human talent on endless consumerism that endlessly eats its own planet. Neither leaves much reason for hope of human space exploration.

Of course the destruction of Earth may end up being a major driving force behind space exploration and settlement too--the super rich of the world may leave a polluted and war-scared Earth for fresher environs. While that may be a contributing reason, somewhat like the Cold War earlier, I very much hope it does not become our main reason. It seems pretty irresponsible to me.

Rather, I would prefer that we use our ability to make artificial environments in space to learn how to create and manage a sustainable artificial Earth. We need to come to realize that "nature", in the sense of "places and processes untouched by human actions" no longer exists on Earth, and that the once-"natural" Earth is becoming more and more "artificial".

Over the tens of thousands of years of human existence (and not just recently), humans have increased their number and, by technology, the impact of their presence so massively that what was once a self-managing, evolving wilderness became recently a garden requiring human attention and care, and now is in danger of becoming an Iron Lung if we do not learn, in the words of the title of a book by Walter Truett Anderson, that humans must "Govern Evolution."

Most plans for human settlements in space that I have seen assume taking humans as we presently exist biologically and socially, and creating Earth-like artificial environments in space where humans can live Earth-like lives in Earth-like societies. Applying lessons learned during the creation of such artificial space environments to the creation of a sustainable, evolvable Earth is one of the possible themes for the Earth 3 working group that I will touch on briefly tomorrow.

But as important a reason as this is might be for space settlements, there must be something more compelling and grand.

One of the basic tenants of futures studies is that the future cannot be predicted, but it can and should be envisioned and invented. What is needed, clearly, is a compelling vision coupled with a plausible way to make the dream come true.

I believe we live in a world in which increasing novelties will overwhelming any continuities from the past. We should expect more, greater, and unprecedented change in all of our alternative futures.



If this is so--if most of the future will be composed of things we do now experience now and never have before in human history--then Dator's "Second Law of the Futures" becomes very important for you to consider:

**"Any useful idea about the futures should appear to be ridiculous."**

Developing compelling visions for future space settlements is difficult for many of us to do in 2006. To most people, it is ridiculous even to try.

But it is even harder, in 2006, to come up with a plausible way to bring even compelling visions into reality.

But it is not impossible.

Futurists such as myself use a variety of theories and methods to anticipate and guide things to come. Bruce Cordell, former program manager of Mars/Lunar Advanced Programs at General Dynamics, and now Dean of Natural Sciences at Fullerton College nearby, has recently used several futures methods specifically to forecast the future of space exploration.

Based on the theory of Kondratieff Long Waves, a socio-economic theory that has been used to forecast major social changes for many years, and the theory of Positive Psychology developed more recently by Martin Seligman of the University of Pennsylvania, Cordell's forecast is also supported by age-cohort work done by William Strauss and Neil Howe, initially in their book, *Generations*, and in several publications subsequently.

All three theories--Kondratieff Long Waves, Positive Psychology, and Strauss and Howe's Age-Cohort analysis--independently show that societies cycle through long waves of social and technological change of between 50 and 60 years length.

During certain periods in these cycles, big projects, such as space exploration, are possible while when society is in other periods during the cycle, big projects of any kind are impossible, both technologically and psychologically.

In an article to be published in *Futures Research Quarterly*, titled "21ST Century Waves: Forecasting Technology Booms and Human Expansion into the Cosmos," Cordell specifically predicts when the next era of space exploration will be possible even though it seems impossible now:

**"[L]ong-term trends in science, technology, and human history strongly suggest that the decade from 2015 to 2025 will be the economic, technological, and political analog of the 1960s [the last time big projects were possible]. We should expect unprecedented activities in technology, engineering, and human exploration [then]. The focus will be on large-scale human operations in space."**

I am not willing to agree with Cordell that we can be confident enough in these theories and the historical evidence to predict with certainty that humans WILL return to the moon and go to Mars during the 2015-2025 period. But I do think that the evidence is strong enough that we can use these theories to develop a vision and begin the work necessary to make such a prediction a self-fulfilling prophecy on the basis that what seems to be impossible now, in fact is impossible now, but may seem almost inevitable in ten to twenty years.

But we need more.

At the present time, most effort towards space is still under the control of a very few national governments. But the future of the nation-state system itself is in doubt. It is by no means clear that the current international system is sufficient to address environmental and economic challenges ahead. And there is every good reason to believe that space settlement also should be at least a multinational effort, if not entirely a transnational venture.

At the same time, what was once a fantasy, and then a dream, is becoming a reality--private entrepreneurial ventures into space.

Even though the future of the current global economic system is in doubt, it is utterly reasonable to assume that vision, risk-taking, and entrepreneurship will continue to be expressed and grow as age-cohorts worldwide, accustomed to having the nation-state tell them what to do and to having the nation-state do all the difficult things for them die, and are replaced by people--like you--far more accustomed to doing things for yourselves, but in cooperation with other willing and able selves, uncoerced and unfunded by the old-fashioned authoritarian nation-state.

It is the self-reliant, yet highly cooperative and creative spirit of the Millennial Generation worldwide that gives me the greatest reason to be hopeful about space exploration in the future. And that spirit is almost irresistible, if the forecasts based on the rising K-Wave are also accurate.

In addition, from my perspective, one voluntary sector that seems to have enormous and growing power, wealth, and vision is that of various religious groups.

There already are some religious organizations that have expressed interests in space exploration and settlement and there may be more in the future if governments fail, the neoliberal global economy falters, but faith strengthens and continues to bloom.

#### **Akio Inoue, "Concepts related to the Japan International Space Culture Congress," Tenri City**

At the present time, Malaysia is the Islamic nation that seems to be taking the lead in developing spacefaring capabilities. I do not know of any discussion of pan-Islamic cooperation in space yet, but I expect to see it emerge. Islam does not fit easily into the structures of narrow nationalism, seeing itself primarily as a global community of believers.

#### **"Malaysia Conference Considers How To Practice Islam In Space"** *SpaceDaily, April 20, 2006*

So also, the Roman Catholic Church, which has expertise in astronomy and has expressed theological perspectives on space exploration, could mobilize the faithful for space settlement.

#### ***The Significance of The Martian Frontier: A Roman Catholic Perspective***

And if you are going to call yourself "Moonies", then you certainly need to give serious thought to living on the moon.

In what is still one of the most important volumes on space exploration and settlement, *Interstellar Migration and the Human Experience* (University of California Press, 1985), Ben Finney and Eric Jones argue that

**“Living in space would represent a logical extension to the technological path our ancestors have been following for some five million years.”**

At first, humans in space will almost certainly try to make space as Earthlike as possible, but it is highly likely that Earthkind in space will eventually become Spacekind--no longer defining everything, or even anything, by “what it was like back home on Earth.” Thus, as Ben Finney says

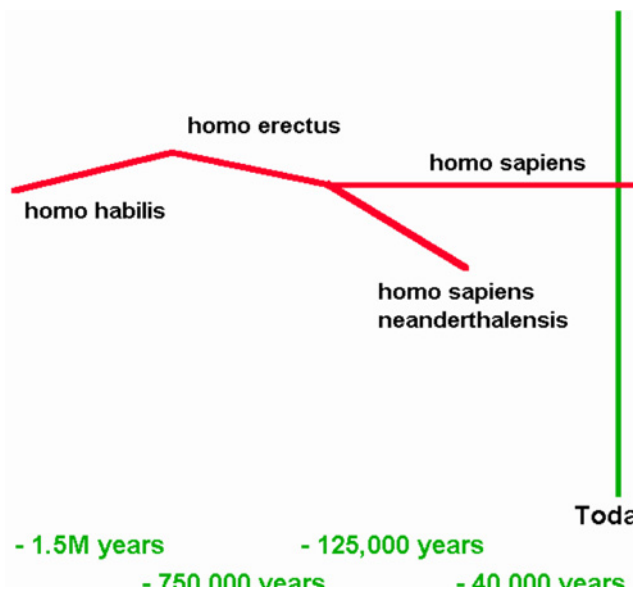
**“Evolutionary processes pent up on Earth will be unleashed in space, and the most dramatic explosion of speciation the universe has ever seen will occur.”**

This “natural” evolutionary process may be greatly aided by advances in genetic and molecular engineering so that a myriad of new intelligent lifeforms may arise or be created as life moves from Earth to various places in the solar system and beyond.

Continuing rapid advances in artificial life, artificial intelligence, and genetic engineering seem to be pushing humanity and all life on the planet towards what the Sri Lankan futurist, Susantha Goonatilake, calls Merged Evolution, or what the American futurist, Ray Kurzweil, calls, *The Singularity*.

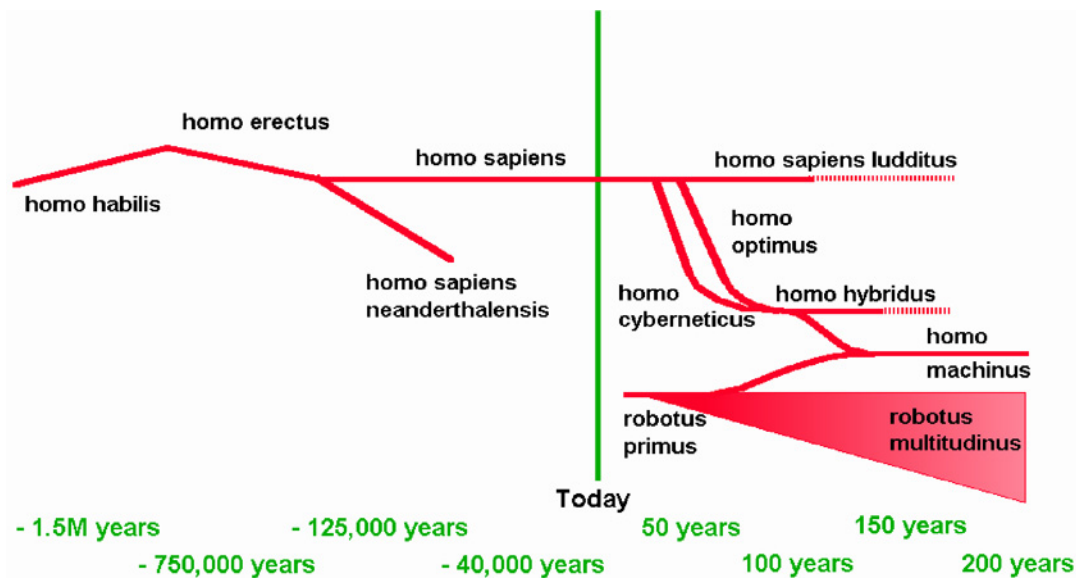
One consequence of this is that instead of making space settlements as Earth like as possible--the process you know as terraforming--we might instead try to modify human life for extraterrestrial environments.

However, Ian Pearson reminds us



that once there were several species of homosapiens living on Earth together--most notably *homosapiens Neaderthal* and what we now proudly call *homosapiens sapiens*.

Pearson, along with Kurzweil and myself, suggest we now might be on the verge of an explosion of intelligent life forms and cultures of which humans are not necessarily the dominant form.



Some, such as Bill Joy--and I suppose most of humanity--deplore and fear this potential development.

But not me: I welcome it.

My last name, Dator, might be the key for why I feel that way. As any of you know, who know Swedish, my name, in Swedish, means, "computer". If you were to google my name you would find many pages that look like this:

**Dator.sladd.net**

Personlig hemsida om gamla datorer och vad man kan ha dem till.

**dator.sladd.net/** - 7k - Cached - Similar pages

**Dator** - susning.nu

**Dator** är ett svenskt ord för datamaskin . Ordet dator tillskrivs Börje Langefors år 1968 och är avlett från data. Först i tryck i DN 26 april detta år. ...

susning.nu/**Dator** - 12k - Cached - Similar pages

Tyst **dator**

Tyst **Dator** behandlar ljudergonomi och den växande marknaden för akustiskt komfortabel informationsteknologi.

www.silent.se/**dator/** - 132k - Cached - Similar pages

Jim **Dator** - Wikipedia, the free encyclopedia

James Allen (Jim) **Dator** is Professor, and Director of the Hawaii Research Center for Futures Studies, Department of Political Science, University of Hawaii ...

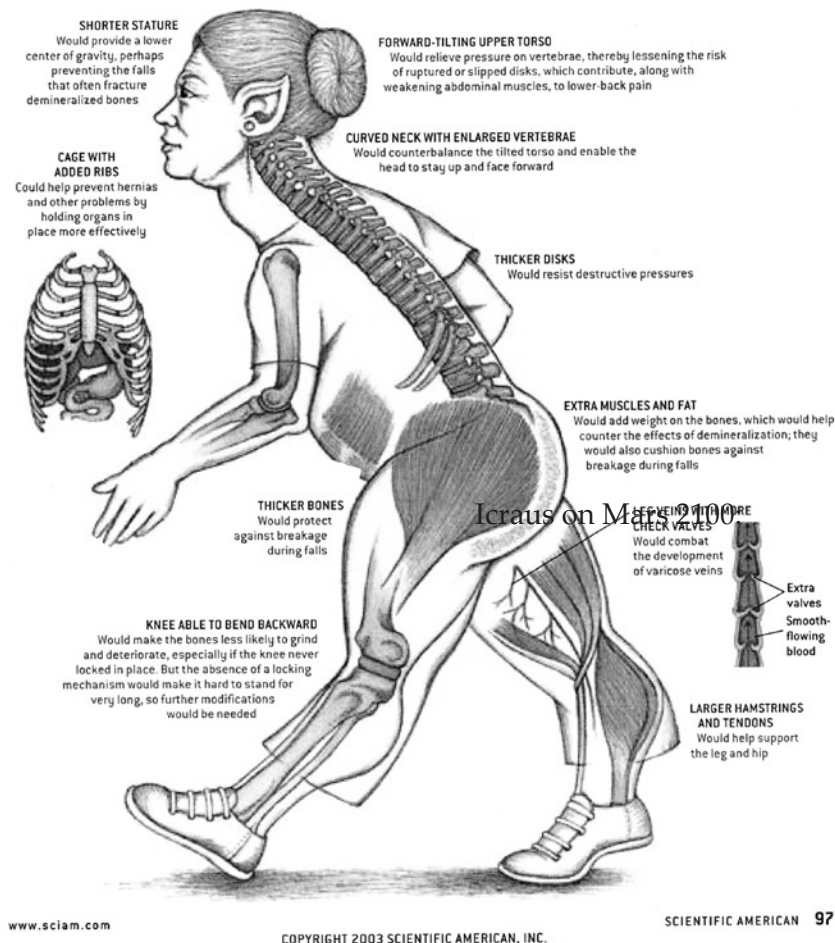
en.wikipedia.org/wiki/Jim\_**Dator** - 12k - Cached - Similar pages

and I will neither confirm nor deny at this time that I am an inferior beta version of robotic artificial intelligence.

But I can assure you that, though inferior now, I am the wave of a future. If beta comes, can delta be far behind?



Recently Jay Olshansky pointed out several severe flaws in human body design even for life on Earth. Here is what humans should probably look like if we were to be intelligently re-designed for living on Earth:



But note how much that design does in fact already look like me. And I can confess to you that I am indeed slowly adapting myself for life on Mars. My once sleek, thin, muscular body has, over the years, become more hunched, with a firm thick-plated back, and a soft underbelly.

I am convinced a good design for intelligent life on Mars is like that a turtle with head and limbs that can quickly retract into a stiff shell to protect itself from sudden blasts of solar or cosmic rays.

But I also look forward to flying, or at least gliding on Mars, so that intelligent life on Mars might instead resemble a winged turtle.

*Icraus on Mars 2100:*

What do you think?

I have tried to suggest several ways and reasons for human settlements in space in the foreseeable future. I challenge you to come up with more and better ones. I am certain you can and will do that.

So I will end with my favorite space poem, which was written, not at all actually to be about outer space--free space--but nonetheless seems to capture the essence of my message today.

It is by the late 19th, early 20th century poet, Walt Whitman:

**A noiseless patient spider,  
I mark'd where on a little promontory it stood isolated,  
Mark'd how to explore the vacant vast surrounding,  
It launch'd forth filament, filament, filament, out of itself,  
Ever unreeling them, ever tirelessly speeding them.**

**And you O my soul where you stand,  
Surrounded, detached, in measureless oceans of space,  
Ceaselessly musing, venturing, throwing, seeking the spheres  
To connect them,  
Till the bridge you will need be form'd,  
Till the ductile anchor hold,  
Till the gossamer thread you fling catch somewhere, O my soul.**



**Jack Boyd**  
NASA Ames Research Center

John W. (Jack) Boyd was recently brought back as the Senior Advisor to the Ames Center Director. Prior to this position he was the Ames Historian and the Ombudsman for the Center. As the official historian, Mr. Boyd captured important historical information for future publications concerning significant research accomplishments of this Center.

Previous to this position, he was the Executive Assistant to the Director at NASA Ames Research Center for over 8 years. Mr. Boyd began his career at Ames in 1947, when it was still the National Advisory Committee for Aeronautics (NACA) Ames Aeronautical Laboratory, and worked as an aeronautical research engineer conducting wind tunnel studies of the supersonic and subsonic characteristics of fighter/bomber aircraft. He later pioneered early research on the design of unmanned planetary probes to explore Mars and Venus, and helped develop early configurations for the Mercury, Gemini, and Apollo capsules, as well as the space shuttle design. He is a graduate of George Washington High School in Danville, Virginia, Virginia Tech; and Stanford University.

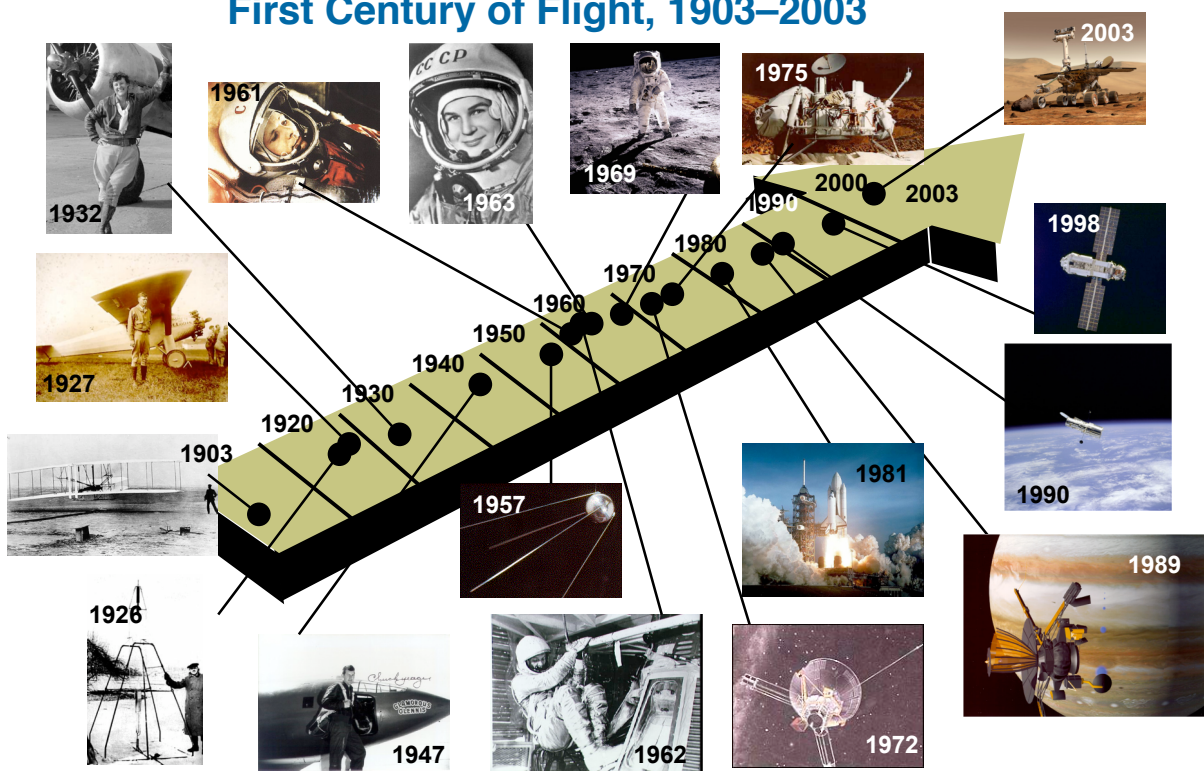
Mr. Boyd has served as Deputy Director of Dryden Flight Research Center, Deputy and Associate Director of Ames Research Center, and Associate Administrator for Management at NASA Headquarters. Additionally, he was also chancellor for Research for The University of Texas System. He has also been an adjunct professor at The University of Texas (Austin, El Paso, and Pan American campuses) teaching courses in aerodynamics, introduction to engineering, and the history of space flight.







### First Century of Flight, 1903–2003





### First Century of Flight, Ames Visitors



Charles Lindbergh



Orville Wright



Neil Armstrong



Chuck Yeager



Wernher Von Braun



John Glenn



Jimmy Doolittle



Edward Teller

3 NGEC - 8/16/06 - [JBoyd;jf]



### NACA Research Centers

**NACA**

**NASA**



Joseph S. Ames

**Langley**

**Ames**

**Dryden**

**Lewis**

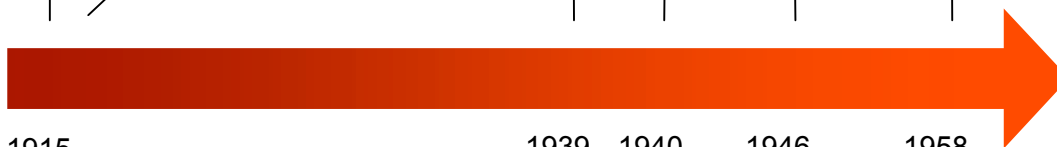
1915

1939

1940

1946

1958

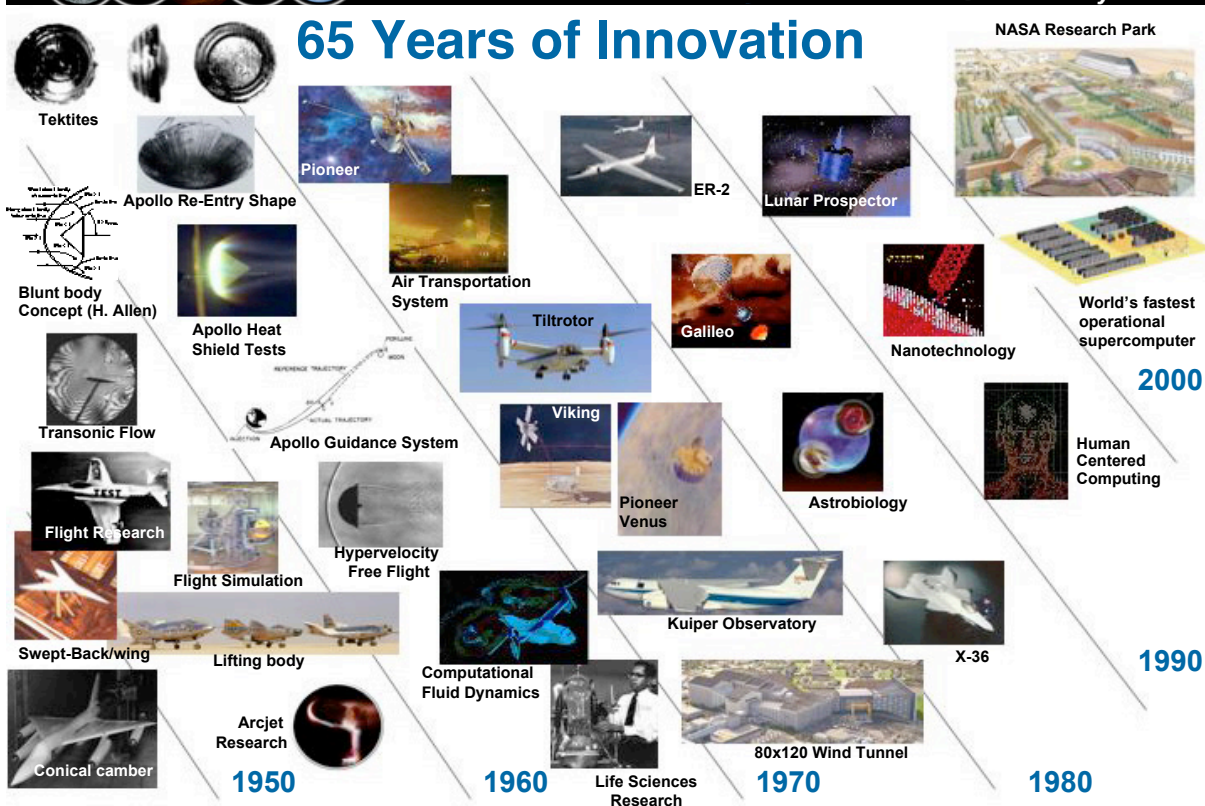


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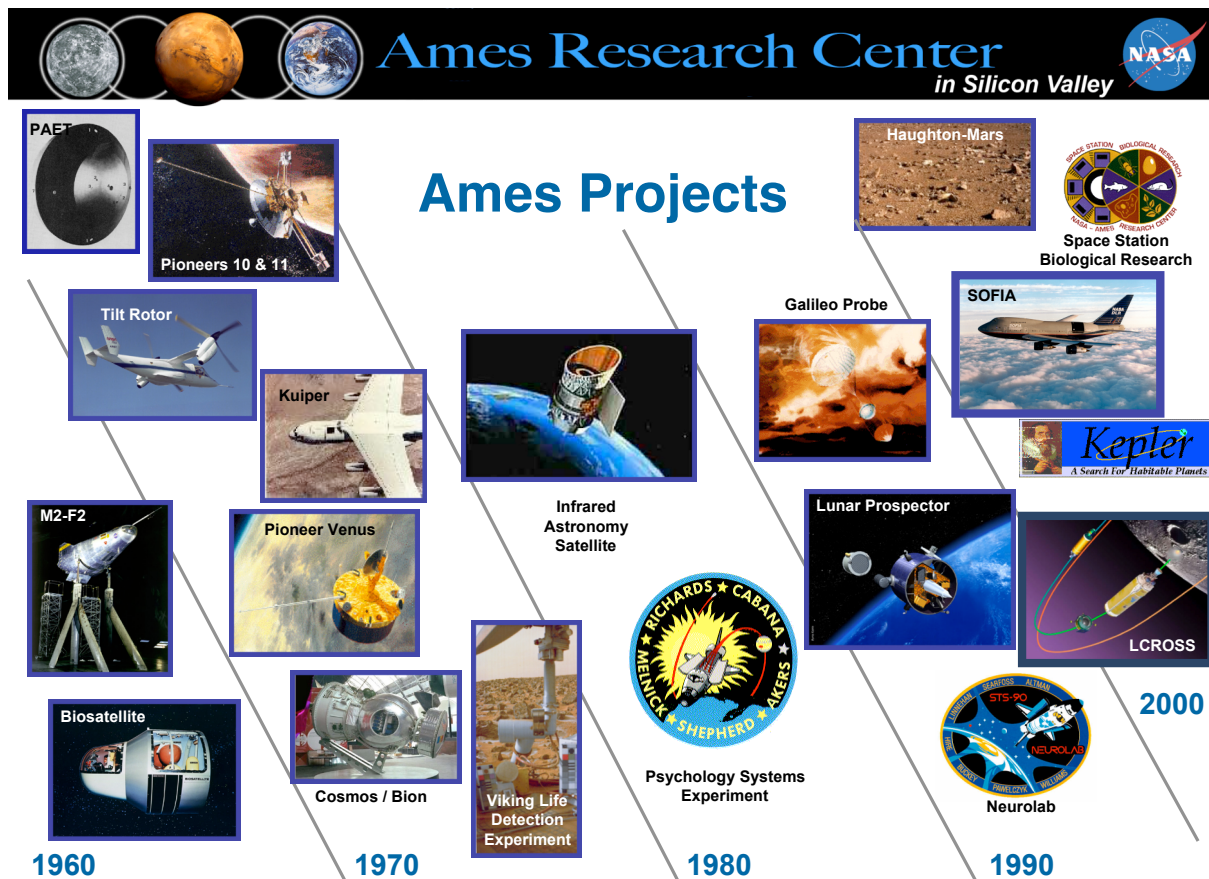




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## Ames Research Center

in Silicon Valley

### NASA Ames Research Center Today – founded 1939

Science (Earth-Life-Space): Astrobiology- the study of life in the universe  
Science Missions

- Stratospheric Observatory For Infrared Astronomy
- Kepler Mission-Search for Habitable Planets

Exploration Systems Development

- Lunar Crater Observation and Sensing Satellite
- Thermal Protection Systems
- Mission Operations
- Integrated Systems Health Management
- Autonomy & Reliable Software

Supporting Technologies

- Information Technology (Autonomy, Human Factors, High-End Computing)

Aviation and Aeronautics

- Air Traffic Management and Control

Education

Innovative Collaborations

- NASA Research Park
- University Affiliated Research Center

2300 Employees

- (1200 Civil Service/1100 Contractor and Other)

\$600+ M Annual Budget





## Astrobiology

- Scientific study of life in the universe
- Three fundamental questions
  - How does life begin and evolve?
  - Does life exist elsewhere in the universe?
  - What is life's future on Earth and beyond?
- NASA Astrobiology Institute at Ames
  - Dr. Rosalind Grymes, Executive Director
  - Dr. Bruce Runnegar, Science Director
  - 12 lead member institutions



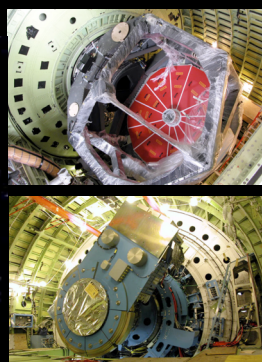
9 NGEC - 8/16/06 - [JBoyd:jf]



## SOFIA

SOFIA will explore the infrared universe flying above interference from the Earth's water vapor atmosphere

National Academy priority from Decadal Surveys, 1991 & 2001



Airborne observatory

2.8 m IR telescope in 747 aircraft

160 flights per year

10 NGEC - 8/16/06 - [JBoyd:jf]



## Crew Exploration Vehicle/Crew Launch Vehicle

- **CEV Thermal Protection System Advanced Development Project Office assigned to Ames**
  - Primary roles
    - Maturing ablative material technology
    - Developing TPS ablative material response model
    - Down-selection to a single TPS solution by CEV PDR
    - Supporting aerothermal environments and verification (JSC lead)
    - Project management support, systems engineering support for CEV
  - Mult-center team: ARC, JSC, KSC, LaRC, JPL; Lead: James Reuther
  - Industry to lead detailed design, fabrication, test and verification
- **Mission Operations System for CEV/CLV**
  - ARC is part of the team that will design, develop, and implement the Launch Mission Systems, and Command and Control capability for CEV/CLV
    - Team includes JSC, GSFC, JPL, KSC
- **Integrated Systems Health Management for Exploration**
  - ARC leads the ESMD Technology Development Program's R&D effort in Integrated Systems Health Management for Exploration
    - 5 year research effort focused on CEV, CLV, and RLEP
    - Team includes MSFC, JPL, GRC, and JSC
- **Spacecraft Autonomy for Exploration**
  - ARC is leading the ESMD Technology Development Program's R&D effort in Autonomy for Exploration
    - 5 year research effort focused on CEV, CLV, and RLEP
    - Includes additional work at JSC, LaRC, and JPL

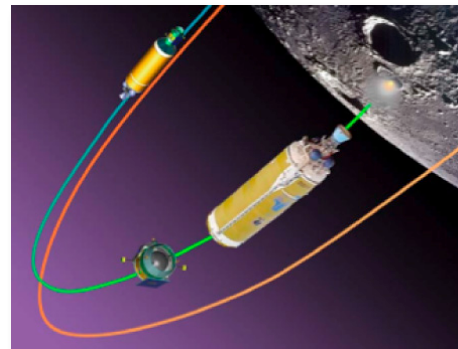




## Lunar Crater Observation and Sensing Satellite (LCROSS)

### *Ames – piggy back on LRO*

- Lunar Kinetic Impactor Mission employed to reveal the presence and nature of water ice on the Moon's South Pole
  - Delivers a 2000 kg impactor to a lunar crater and measures water signatures with an *in situ* Shepherding Spacecraft that then becomes a 700 kg secondary impactor.
- Mission Objectives
  - Advance the Vision for Space Exploration by confirming the presence or absence of water ice at the Moon's South Pole.
  - Provide technologies and modular, reconfigurable subsystems that can be used to support future RLEP mission architectures.
  - Inspire public interest in NASA's Exploration Vision.

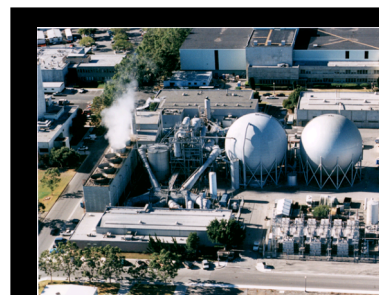


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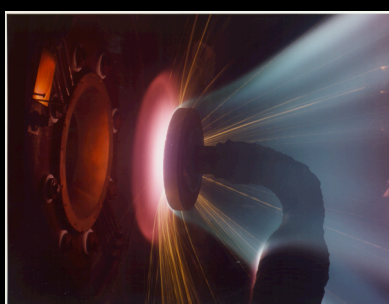


## Thermal Protection Materials and Arc-Jet Facility

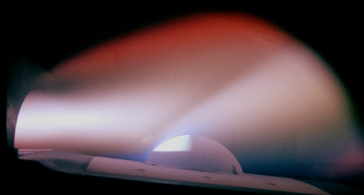
Testing and/or materials for all US Planetary entry systems; Support for Apollo, Shuttle, and Crew Exploration Vehicle



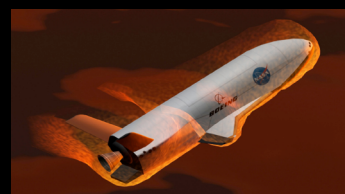
Ames Arcjet Complex



Ablative Thermal Protection Testing



Mars Rover Entry System Test



Human rated vehicle design & test (X-37)

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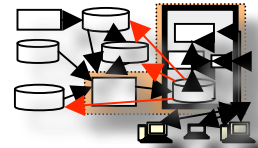


## Information Science & Technology

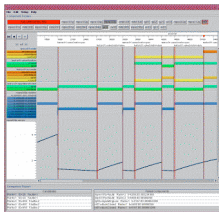
Intelligent Adaptive Systems  
Human/machine Interface  
Large Data Sets and Datamining



Mars Science Laboratory '09

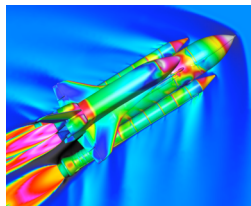


**Project Columbia:**  
One of the world's fastest super computers

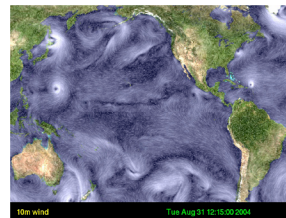


Integrated Systems Health Management

### Super Computing



Designing the next generations



Global Climate modeling

15 NGEC - 8/16/06 - [JBoyd;jf]



## Project Columbia Integration and Installation



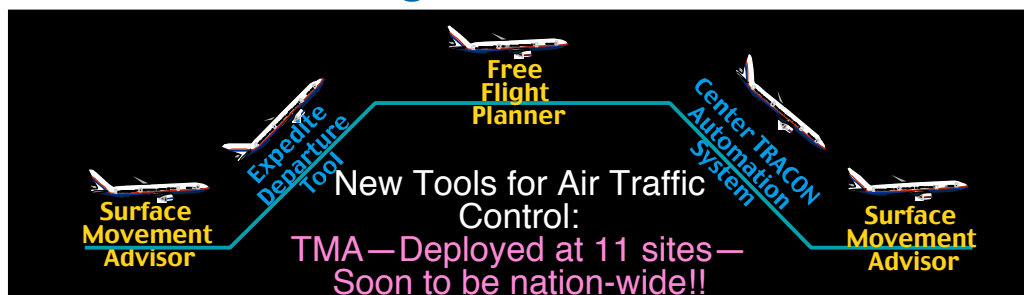
- Provides 61 TFLOPs (10/20/04)
- Conceived, designed, built, and deployed in just 120 days
- Largest SGI system in the world with over 10,000 Intel Itanium 2 processors
- Computation and simulation for Crew Exploration Vehicle, Crew Launch vehicle, Earth Science, Astrophysics, and more

**Record Time and Budget!!**

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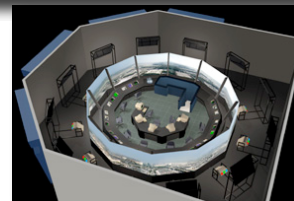


## Air Traffic Management/Air Traffic Control



### Impact: Surface Management System (SMS)

*Estimated annual savings of \$315M/year to airlines*



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## New Models-UARC

### NASA's first University Affiliated Research Center

- 10 year, \$330 M contract between NASA Ames and University of California.
- UC Santa Cruz is lead UC institution-Ranked 1st in Space Science by ISI
- Beyond grants and support contracts
- Tasks that are part of NASA's critical milestones
- Flexibility to change tasks as needs arise
- UC: 10 Campuses, 3 National Laboratories
- \$18B annual budget
- 4 UC campuses rated among top 15 worldwide



UC President Robert Dynes

### 3 Bay Area Campuses



**University of California**  
*It Starts Here*

### UC System







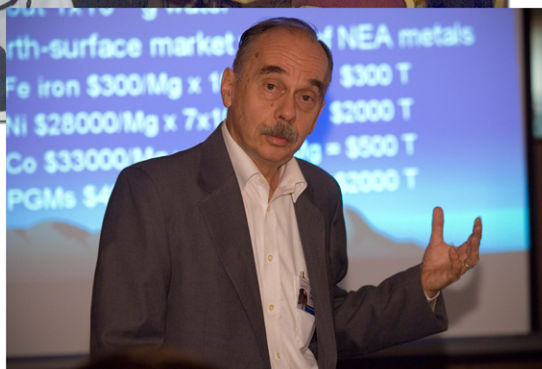
**Science Presentations  
to Working Groups from the  
Next Generation Exploration Conference**



**John Lewis**  
University of Arizona

John S. Lewis is Professor of Planetary Sciences and Co-Director of the Space Engineering Research Center at the University of Arizona. He was previously a Professor of Planetary Sciences at MIT and Visiting Professor at the California Institute of Technology. Most recently, he was a Visiting Professor at Tsinghua University in Beijing for the 2005-2006 academic year. His research interests are related to the application of chemistry to astronomical

problems, including the origin of the Solar System, the evolution of planetary atmospheres, the origin of organic matter in planetary environments, the chemical structure and history of icy satellites, the hazards of comet and asteroid bombardment of Earth, and the extraction, processing, and use of the energy and material resources of nearby space. He has served as member or Chairman of a wide variety of NASA and NAS advisory committees and review panels. He has written 17 books, including undergraduate and graduate level texts and popular science books, and has authored over 150 scientific publications.







# Asteroid Exploration and Exploitation

John S. Lewis  
LPL, University of Arizona and  
Tsinghua University

## Think Outside the Box...

...if you can!



# The NEA Population



- About 1200 one-kilometer-sized NEAs
- About 400,000 100-m sized NEAs
- Periods generally 0.9 to 7 years
- Orbital inclinations generally 10-20°
- Eccentricities 0 to 0.9; mostly near 0.5
- About 30% will eventually hit Earth
- About 20% are easier to land on than the Moon

## Data on NEO Compositions

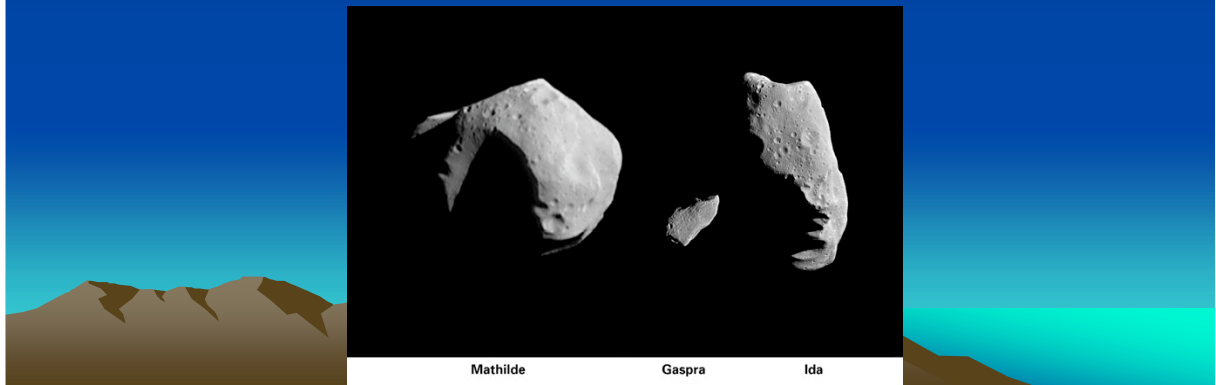
- Over 10,000 analyzed meteorites, most of which are from NEO parents
  - About 50 different classes from steel to mud
- Remote sensing UV/vis/near IR
  - Many spectral classes; some match meteorites
- Spacecraft *in situ* measurements
- Sample return (*Hayabusa* (?))



## Traits of Economically Desirable NEAs

Easy access from LEO/HEEO

- Easy return to LEO/HEEO
- Abundance of useful materials
- Simple, efficient processing schemes



## Easy Access from LEO Means:

- Perihelion (or aphelion) close to 1 AU
- Small eccentricity
- Low inclination

These factors combined allow low outbound  $\Delta V$ s (from LEO to soft landing)

About 240 km-sized NEAs have

$$\Delta V_{\text{out}} < 6 \text{ km s}^{-1} \text{ (vs. 6.1 for the Moon)}$$



## Easy Return to LEO Means:

- Perihelion (aphelion) close to 1 AU
- Small cross-range distance between orbits
- Favorable orbital phasing
- Use of aerocapture at Earth

These factors allow low inbound  $\Delta V$ s (from asteroid surface to LEO).

Many NEAs have  $\Delta V_{\text{in}} < 500 \text{ m s}^{-1}$  (some as low as  $60 \text{ m s}^{-1}$ , compared to  $3000 \text{ m s}^{-1}$  for Moon)

## Abundance of Useful Materials 1

- What are the most useful materials?
  - Water (ice, -OH silicates, hydrated salts) for
    - Propellants
    - Life support
  - Native ferrous metals (Fe, Ni) for structures
  - Bulk regolith for radiation shielding
  - Platinum-group metals (PGMs) for Earth
  - Semiconductor nonmetals (Si, Ga, Ge, As,...) for Earth or Solar Power Satellites

## Abundance of Useful Materials 2

- Comparative abundances
  - Water
    - C, D, P chondrites have 1 to >20% H<sub>2</sub>O; extinct NEO comet cores may be 60% water ice
    - Mature regolith SW hydrogen reaches maximum of about 100 ppm in ilmenite-rich mare basins (water equivalent 0.1% assuming perfect recovery)
  - Metals
    - To 99% in M asteroids; 5-30% in chondrites
    - Lunar regolith contains 0.1 to 0.5 % asteroidal metals

## Simple, Efficient Processing Schemes

- “Simple and Efficient”
  - Low energy consumption per kg of product
  - Processes require little or no consumables
  - Few **mechanical** parts
  - Modular design for ease of repair
  - Highly autonomous operation
  - On-board AI/expert systems for process control
  - Self-diagnosis and self-repair capabilities
  - Maximal use of low-grade (solar thermal) energy
  - Regenerative heat capture wherever possible

# Examples of Processing Schemes

“Industrial Cosmochemistry”

- Ice extraction by melting and sublimation of native ice using solar or nuclear power
- Water extraction from –OH silicates or hydrated salts by solar or nuclear heating
- Electrolysis of water and liquefaction of H<sub>2</sub>O
- Ferrous metal volatilization, separation, purification, and deposition by the gaseous Mond process



## Magnitude of NEA Resources

- Total NEA mass about  $4 \times 10^{18}$  g
- About  $1 \times 10^{18}$  g ferrous metals
- About  $1 \times 10^{18}$  g water
- Earth-surface market value of NEA metals
  - Fe iron  $\$300/\text{Mg} \times 10^{12} \text{ Mg} = \$300 \text{ T}$
  - Ni  $\$28000/\text{Mg} \times 7 \times 10^{10} \text{ Mg} = \$2000 \text{ T}$
  - Co  $\$33000/\text{Mg} \times 1.5 \times 10^{10} \text{ Mg} = \$500 \text{ T}$
  - PGMs  $\$40/\text{g} \times 5 \times 10^7 \text{ Mg} = \$2000 \text{ T}$



## High-value Imports for Earth

- PGM prices (\$US/troy ounce)
  - Pt \$1032
  - Pd 276
  - Os 380
  - Ir 380
  - Rh 4650
  - Ru 165
- Nonmetals for semiconductors
  - In(\$27/toz), Ga (\$16/toz), Ge, As, Sb, Se...



## High-Utility Materials for Use in Space

- Structural metals
  - High-purity iron from Mond process
    - 99.9999% Fe: strength and corrosion resistance of stainless steel
  - High-precision chemical vapor deposition (CVD) of Ni in molds
    - Custom CVD of Fe/Ni alloys
- Bulk radiation shielding
  - Regolith, metals, water (best)

## One Small Metallic NEA: Amun

- 3554 Amun: smallest known M-type NEA
- Amun is 2000 m in diameter
- Contains about 30x the total amount of metals mined over human history
- Contains  $3 \times 10^{16}$  g of iron
- Contains over  $10^{12}$  g of PGMs with Earth-surface market value of about \$40 T

## Propellants from Water

- Direct use of water as propellant
  - Solar Thermal Propulsion-- STP (“Steam rocket”)
  - Nuclear Thermal Propulsion– NTP
- Electrolysis of water to H<sub>2</sub>/O
  - H<sub>2</sub> STP
  - H<sub>2</sub> NTP
  - H<sub>2</sub>/O<sub>2</sub> chemical propulsion →



## NEAs as Traveling Hotels

- Typical NEAs have perihelia near Earth and aphelia in the heart of the asteroid belt
- NEA regolith provides radiation shielding
- Asteroid materials provide propellants
- Earth-Mars transfer orbits possible
- Traveling hotels/gas stations/factories... colonies?



## The Martian Connection

- NEAs as transportation aids
  - Traveling gas stations
  - Traveling hotels
- Manned Mars mission rehearsals
- Phobos and Deimos as former NEAs parked in areocentric orbit





# Space Colonization

- Asteroids are primarily mine sites, not resorts or suburbs
- Early exploitation should be simple, energy-efficient, and unmanned
- People will arrive as needed
- This vision dates back to Tsiolkovskii (1903) and Goddard (1908)
- Space colonization is not a goal; if it happens it will be as a response to compelling opportunities

## Asteroids Over the Moon?

- Asteroid strong points:
  - Low  $\Delta V_{\text{out}}$
  - Very low  $\Delta V_{\text{in}}$
  - Resource richness and diversity
- Lunar strong points:
  - Short trip times
  - Helium-3 recovery?



## Rôles of Private Enterprise

- Low-cost *competitive* access to space
- Large-scale *competitive* mineral exploration
- Efficient, *competitive* resource exploitation
- Construction and operation of communication and transportation hubs (LEO, GEO, HEEO, lunar L1, etc.)

*We CANNOT AFFORD a centrally-controlled, duplication-free, government-dominated effort*

## Tsiolkovskii's (1904) 14 Points #1-7

1. Rocket engine tests
2. Single stage rocket flights (1926)
3. Multi-stage rocket flights (1952)
4. Unmanned orbital flight (1957)
5. Manned orbital flight (1961)
6. Prolonged manned orbital flight (1965)
7. Experimental air recycling using plants

## Tsiolkovskii's points 8-14

8. Spacesuits for use outside spacecraft (1965)
9. Space agriculture as a source of food
10. Earth-orbiting space colonies
11. Use of solar energy for transportation and power in space
12. Exploitation of asteroid resources
13. Space industrialization
14. Perfection of mankind and society

## Suggested Reading

- JS Lewis and RA Lewis, *Space Resources: Breaking the Bonds of Earth*, 407 pp. Columbia Univ. Press, (1987)
- MF McKay, DS McKay and MB Duke, eds., *Space Resources*, 942 pp. NASA SP-509 (1992)
- JS Lewis, MS Matthews and M Guerrieri, eds., *Resources of Near-Earth Space*, Univ. of Arizona Press, Tucson. 977 pp. (1993)
- JS Lewis, *Mining the Sky: Untold Riches from the Asteroids, Comets, and Planets*, Addison-Wesley, Reading, MA. 274 pp. (1996)



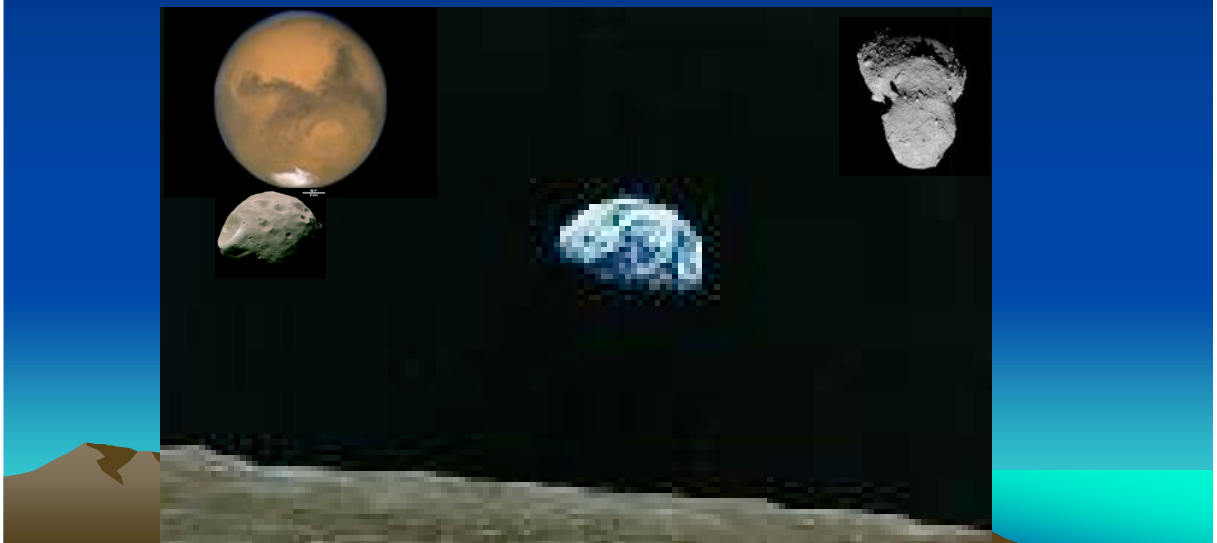
# Legal Regime for Space Resource Utilization

JS Lewis and CF Lewis, A Proposed International Legal Regime for the Era of Private Commercial Utilization of Space. *The George Washington International Law Review* 37, 745-767 (2005).



## A New, Broader Perspective

(Back to the Future of Tsiolkovskii and Goddard)





### Bryan Laubscher

Black Line Ascension/Los Alamos National Laboratory

Bryan E. Laubscher received his Ph.D. in physics in 1994 from the University of New Mexico with a concentration in astrophysics. He is currently on entrepreneurial leave from Los Alamos National Laboratory where he is a project leader and he has worked in various capacities for 16 years. His past projects include LANL's portion of the Sloan Digital Sky Survey, Magdalena Ridge Observatory and a project developing concepts and technologies for space situational awareness. Over the years Bryan has participated in research in astronomy, lidar, non-linear optics, space mission design, space-borne instrumentation design and construction, spacecraft design, novel electromagnetic detection concepts and technologies, detector/receiver system development, spectrometer development, interferometry and participated in many field experiments. Bryan led space elevator development at LANL until going on entrepreneurial leave in 2006. On entrepreneurial leave, Bryan is starting a company to build the strongest materials ever created. These materials are based upon carbon nanotubes – the strongest structures known in nature and the first material identified with sufficient strength-to-weight properties to build a space elevator.



# The Space Elevator and Its Promise for Next Generation Exploration

Bryan Laubscher

Black Line Ascension / Los Alamos National Laboratory

August 17, 2006

*Next Generation Exploration Conference  
NASA Ames Research Center*

## Acknowledgements

- Brad Edwards
- Anders Jorgensen
- Steve Patamia
- Mervyn Kellum
- Black Line Ascension
- Los Alamos National Laboratory
- Institute for Scientific Research
- NASA



# Support for Visionaries

- “The flying machine which will really fly might be evolved by the combined and continuous efforts of mathematicians and mechanics in from one million to ten million years”
  - The New York Times
    - 9 October 1903
- “We started assembly today”
  - Orville Wright’s Diary
    - 9 October 1903

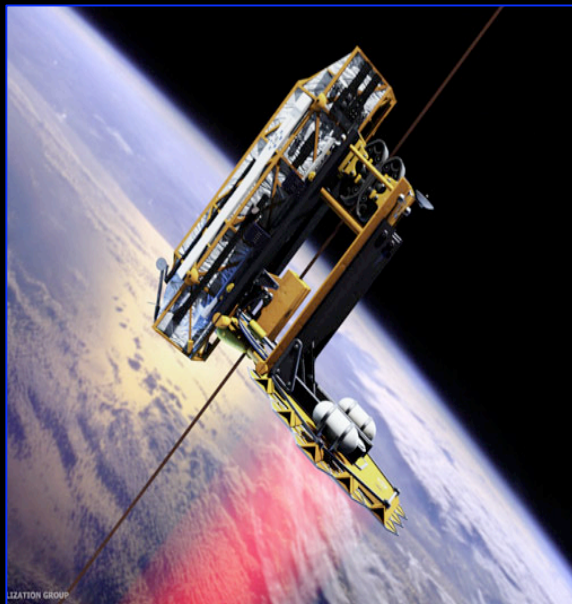
(Source: DARPA)



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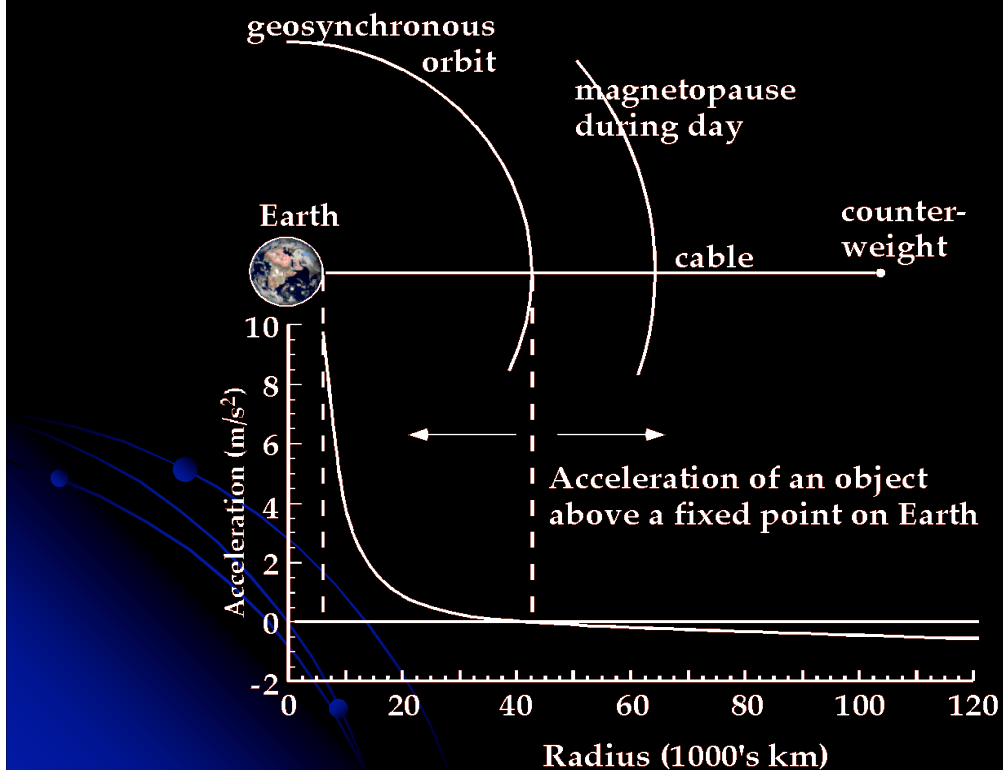
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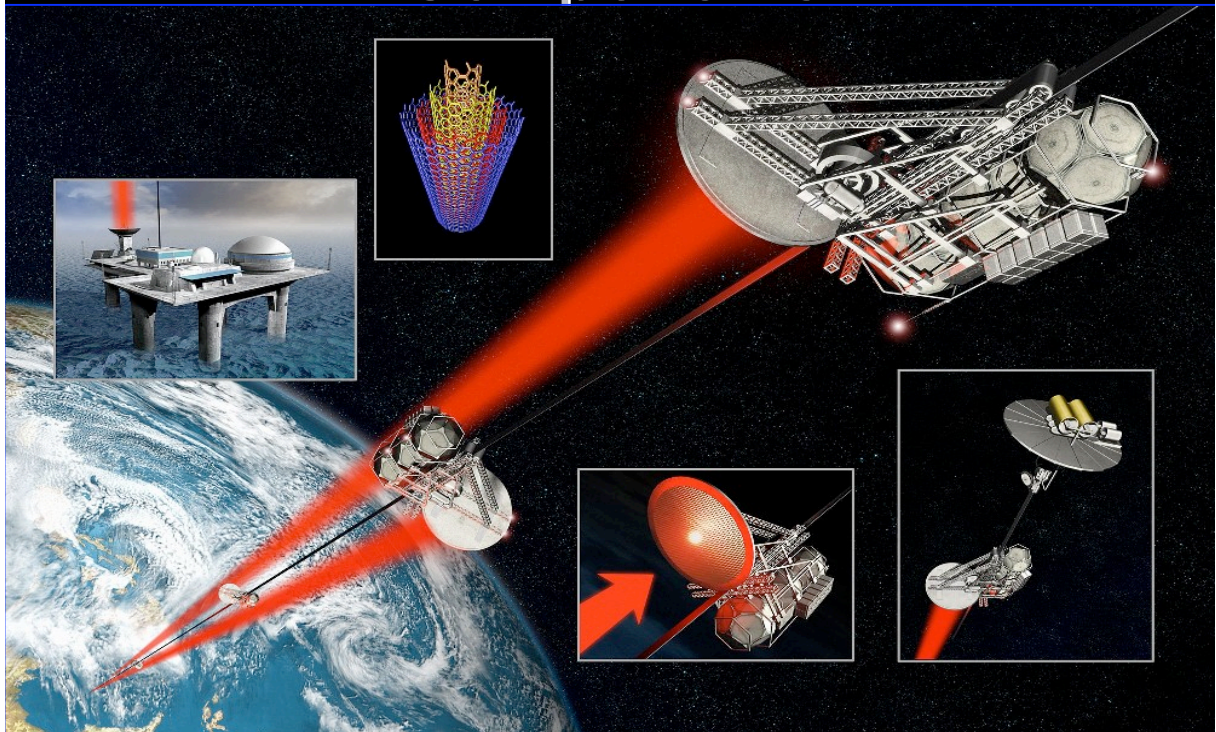




# Space Elevator Basics



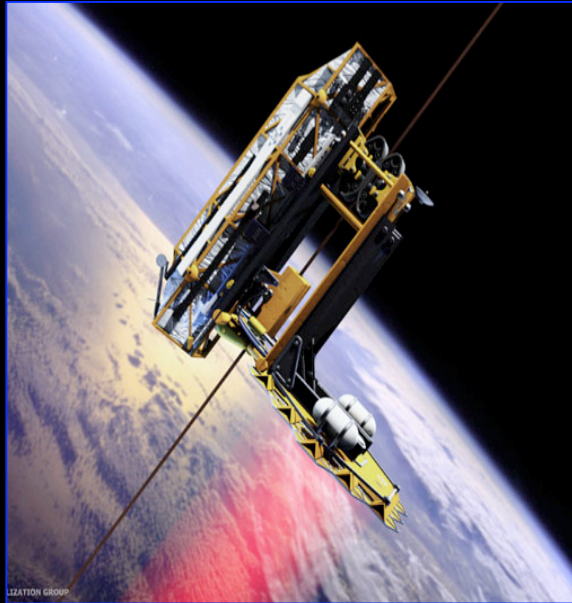
## Space Elevator Major Components



# Directory Slide

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# Launch Costs

Launch System	Launch Cost (\$/kg)
Delta/Atlas to GEO	80,000
Space Shuttle to LEO	64,000
Ariane 5G	23,285
Delta/Atlas to LEO	10,000

(From D. Raitt, ESA/ESTEC., Proc. IAC 2004, Vancouver, Canada)

## Rocket (ln)Efficiency

- The rocket equation explains the efficiency of rocket propulsion:

$$\Delta V = V_p \ln(M_i/M_f)$$

$$\exp[\Delta V / V_p] = M_i/M_f$$

- Large amounts of fuel are needed to accelerate fuel and payload to speed so that the accelerated fuel can be used to accelerate the payload (and remaining fuel) to even greater speed, etc.
- Fuel is lifted to high altitudes before it is burned

## Earth's Gravity Well And other $\Delta V$ s

- Earth's gravity well is so deep that we can barely escape it with chemical rockets. Once you are at LEO, you are “most of the way” to anywhere.

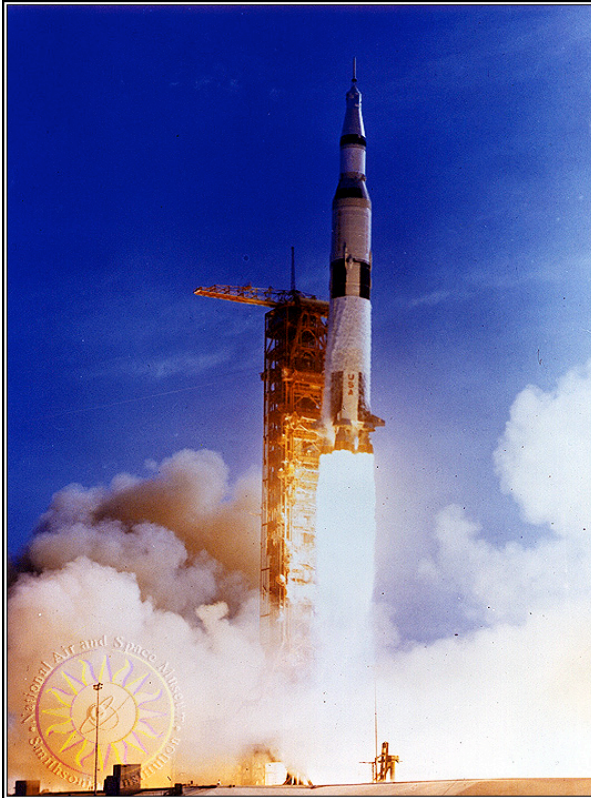
$$\Delta v_{\text{Earth to LEO}} = 9.7 \text{ km/sec}$$

$$\Delta v_{\text{LEO to MoonSurf}} = 5.5 \text{ km/sec}$$

$$\Delta v_{\text{LEO to MarsVic}} = 3.8 \text{ km/sec}$$



# Saturn V



- Built in 1960's for Apollo Program
- Chemical Propulsion
- 5% of mass to LEO
- 2.4% of mass to Trans Lunar Injection
- 1<sup>st</sup> stage, 94% mass ratio
- 2<sup>nd</sup> stage, 90% mass ratio
- 3<sup>rd</sup> stage, 86% mass ratio
- Most powerful rocket ever flown
- No failures

## Mars Mass and Cost with Chemical Rockets

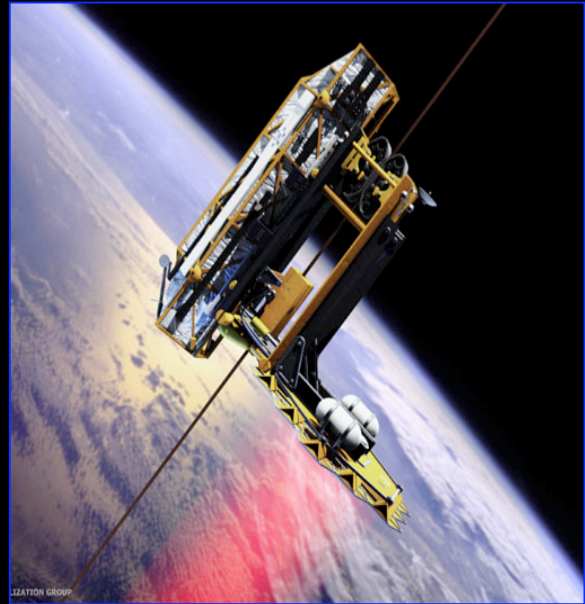
- Test mass from Earth's surface to LEO
  - $M_{\text{ratio}} = 20$
- Test mass from LEO to Mars Transfer Orbit
  - $M_{\text{ratio}} = 2.39$
- Miscellaneous rocket and structure mass
  - $M_{\text{misc}} = 6.9\%$  of the lifted fuel and payload
- Mass Expenditure to Mars
  - Mass Expenditure =  $(1 \text{ kg} \times 20 + 2.39 \text{ kg} \times 20) \times 1.069 = 72.5 \text{ kg}$
- Total cost for 1 kg to Mars
  - Cost to LEO \$10,000 / kg x 72.5 kg = **\$725,000**
  - Good to a factor of 3!
  - Brought to you by the rocket equation and Earth's gravity well and 40 years of experience with the cost of rockets!
- NOTE: These calculations are for cargo that doesn't respire, drink or eat on the way to Mars. For humans the mass that must



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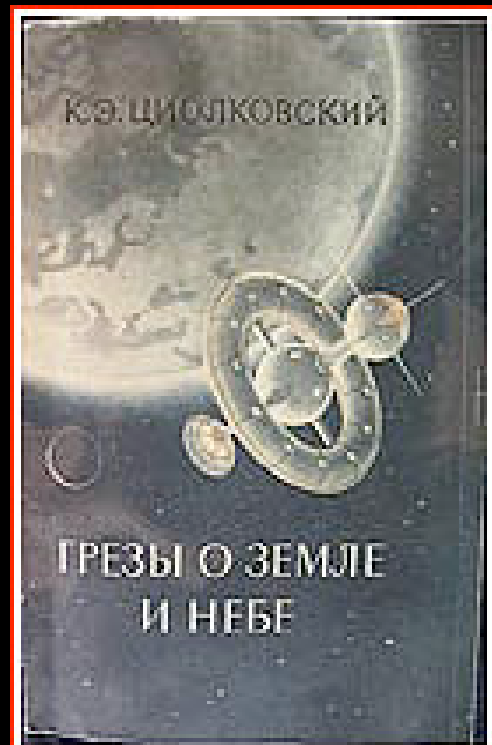
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## Space Elevator Early History

- Konstantin Tsiolkovsky 1895
- Sir Arthur C. Clarke 1945
- John McCarthy early 1950s
- Y. N. Artsutanov 1960
- Isaacs, Vine, Bradner, Bachus, 1966
- Jerome Pearson, 1975

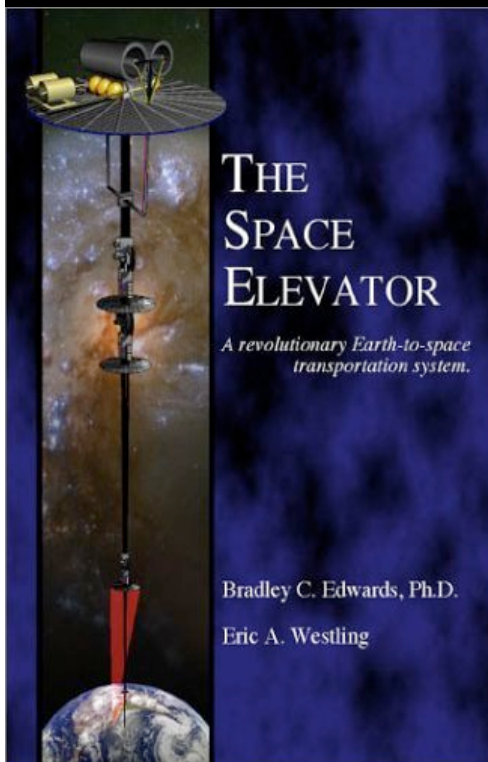


# 1999 Space Elevator Concept

- Carbon nanotubes discovered in 1991
- 1999 NASA Space Elevator Conference
- Reported in press that we would build an elevator in “300 years”
- Piqued Brad Edwards’ interest



## Space Elevator Recent History

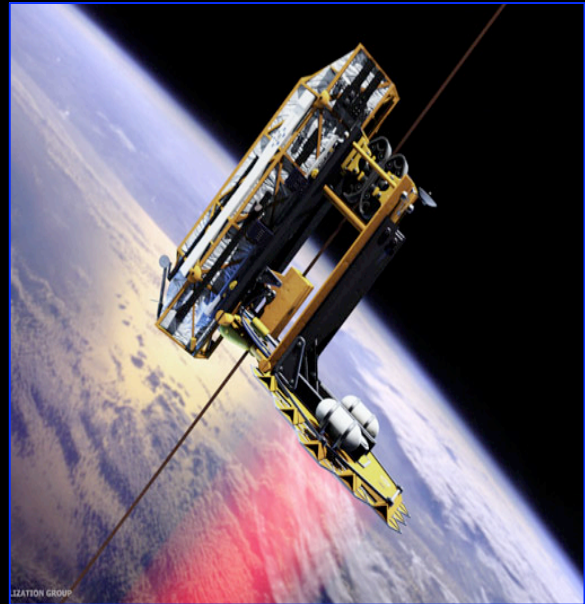


- 2000 Bradley C. Edwards
- 2002 *The Space Elevator* book published
- 1<sup>st</sup> (2002), 2<sup>nd</sup> (2003) and 3<sup>rd</sup> (2004) Annual International Space Elevator Conference
- Space Exploration2005 – 2<sup>nd</sup> Biennial SE Workshop
- 55<sup>th</sup> & 56<sup>th</sup> International Astronautical Congresses

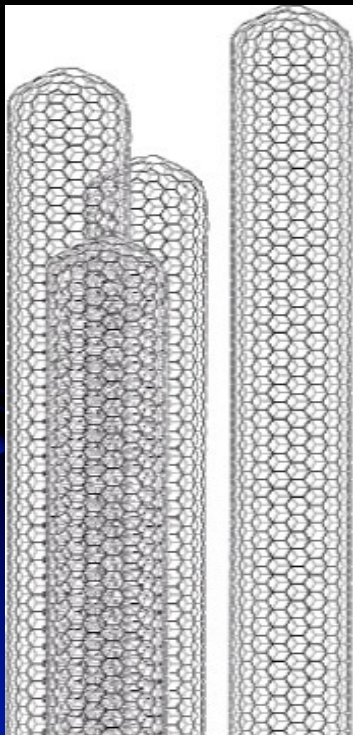
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## Carbon Nanotubes

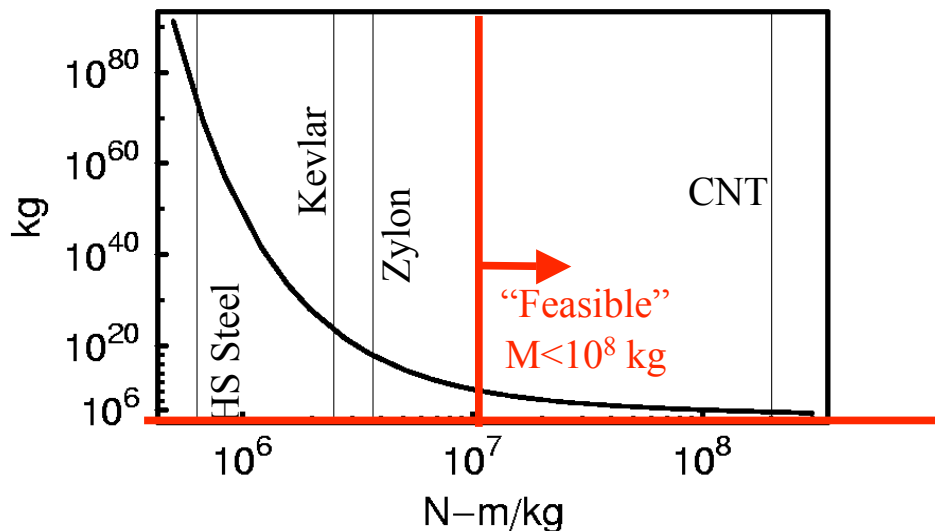


- 1985 Smalley and Curl discover Buckyballs,  $C_{60}$
- 1991 Iijima discovers Carbon Nanotubes
- 1 to many nanometers wide
- As of 2004, 4cm length
- Up to 300 GPa depending on purity (high strength steel – 4GPa)
- 130 GPa required for SE (with safety factor of two)



# Importance of Tensile Strength/Density

Cable Mass as Function of  $\sigma/\rho$  ... Safety Factor = 2



WTC:  $10^9 \text{ kg}$

Earth:  $6 \times 10^{24} \text{ kg}$

Sun:  $2 \times 10^{30} \text{ kg}$

Galaxy:  
 $10^{41} \text{ kg?}$

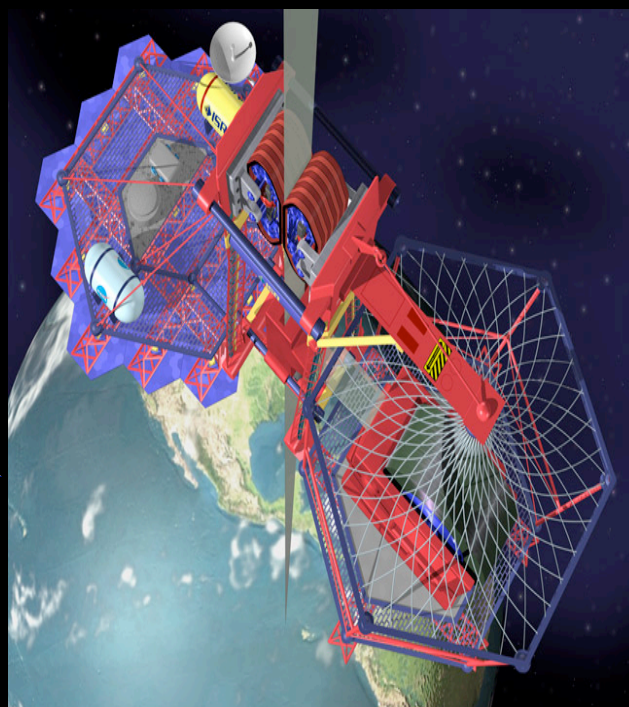
Universe:  
 $10^{52} \text{ kg?}$

(Designed tension half of tensile strength)

(S. E. Patamia, LANL)

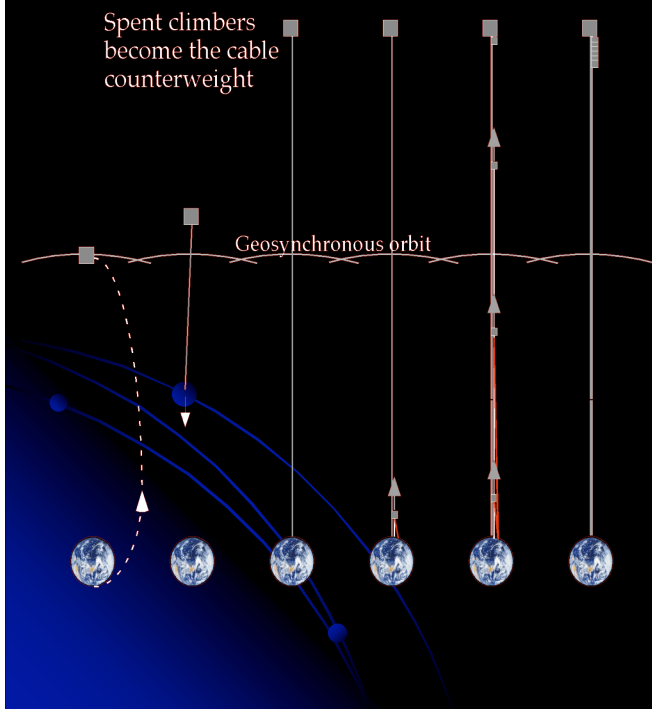
## Initial Space Elevator Parameters

- 100,000 km long (36,000 km GEO orbit)
- 1 meter wide, curved cross section
- Thinner than a sheet of paper
- 20 metric ton capacity
- 650 metric ton ribbon, 800 metric ton counterweight
- 7 metric ton climber, 13 metric ton payload
- Power beamed to climbers from lasers coupled to 10-meter telescopes on Earth
- 7 day trip to geosynchronous
- Launch costs
  - 1<sup>st</sup> Elevator - **\$3000 / kg**
  - 5<sup>th</sup> Elevator - **\$300 / kg**





# Deployment Scenario



- Pilot ribbon
  - 22 – 40 metric tons
  - ~15 cm wide
  - 100,000 km long
- Assemble spacecraft in LEO
- Boost to GEO above ground station
- Deploy ribbon downward
- Thrust to keep rising spacecraft over ground station
- Build up final ribbon by sending up small climbers that attach new ribbon
- 1<sup>st</sup> space elevator finished after two years of assembly
- 2<sup>nd</sup> space elevator built

## Economics: Elevators and Launch Cost

### Bryan's Estimates

- Shatters the paradigm of the rocket equation!
- **\$1.5 B** of research and development
- 1<sup>st</sup> elevator costs **\$18 B**
- 2<sup>nd</sup> elevator costs **\$6.9 B**
- 3<sup>rd</sup> elevator costs **\$4.2 B**
- 4<sup>th</sup> elevator costs **\$2.4 B**
- Economy of scale is operating in a space elevator infrastructure

Ribbons	Launch Cost (\$/kg)
1x20T	3000
2x20T	300
2x20&200T	150
2x20,200,500T	30
Space Shuttle	64,000

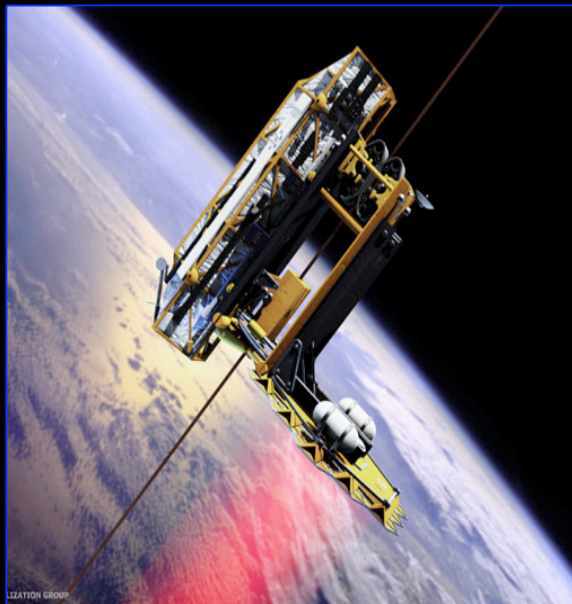
## Transcontinental Railroad Analogy

- Planning began in the 1850's
- Built from 1863-1869 in a "wilderness"
- The Union was fighting the Civil War when it began this project
- Huge initial cost to build the line from Omaha, Nebraska to Sacramento, California
- Built the railroad line as well as infrastructure such as coaling stations and water sources for the steam locomotives
- Created towns in the middle of nowhere
- Unified the United States across the continent and opened the west
- America's greatest engineering feat of the 19<sup>th</sup> century
- New York to San Francisco travel fell from 6 months to 7 days and \$1000 to \$70
- Owners became the some of the richest men in America

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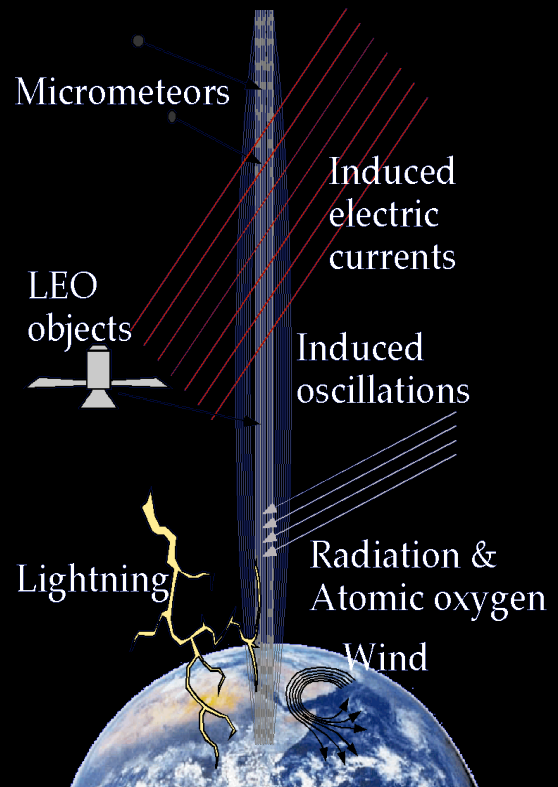


# Technology Development

- Carbon Nanotubes
  - Woven ribbon
  - Composite ribbon
  - Lower cost
  - Manufacturability
- Climbers
  - Compression or pressure on ribbon without damage
  - High reliability
  - Operate in multiple environments
  - Reusable
- Power Beaming
  - Each component has been demonstrated but an integrated system has not been operated
- Human travel on space elevators above LEO requires shielding development
- Deployment Spacecraft
  - Must be launched to LEO in pieces and then assembled
  - Deployment mechanism
  - Power for thrusting and deployment
- At the current, conceptual level of our understanding of the space elevator systems, no “show stoppers” have been identified
- The devil is in the details

## Hazards

- Magnetosphere
- Induced oscillations
- Radiation
- Atomic oxygen in Earth's upper atmosphere
- Environmental Impact: Ionosphere
- Malfunctioning climbers
- Lightning, wind, clouds
- Meteors and space debris
- Satellites
- Health considerations

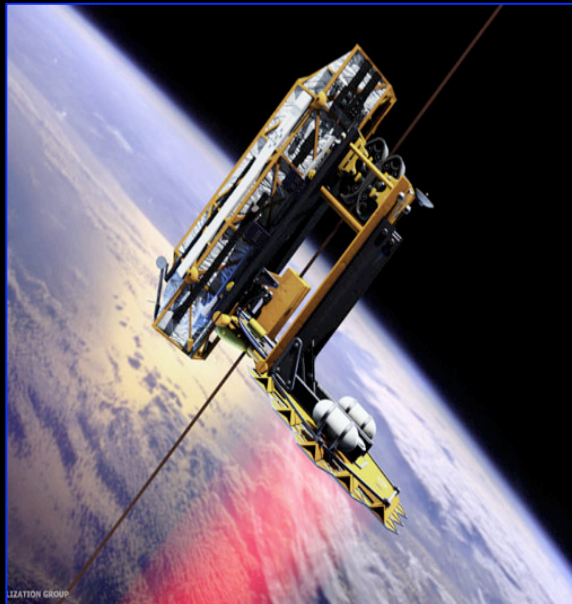




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## Economics: Mission / Spacecraft Costs

- Cost of space missions immediately drops by a factor of 2 because launch costs become a very small fraction of the hardware costs
- Spacecraft can be built much more inexpensively because the launch environment is much more benign
- 100,000 km length
  - Less onboard propulsion to destinations
  - Throw capability beyond Mars and Venus
- Risk is lowered:
  - Spacecraft can be tested after lift but before launch
  - Spacecraft can be brought back down
  - Spacecraft may be retrieved and/or serviced in some cases
  - Rapid, inexpensive launches
- At the same time, riskier missions can be undertaken because unit costs are small.
- Space technology development will be accelerated

# Space Solar Power

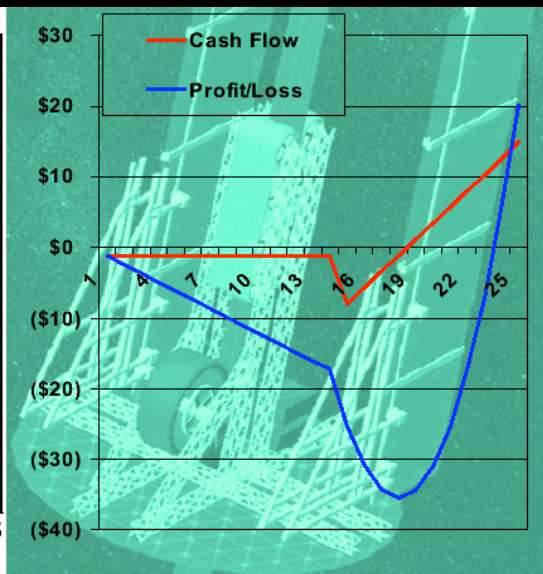
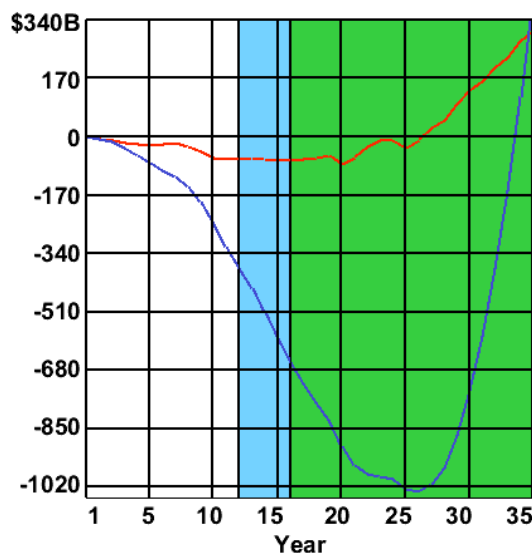
- SSP is possibly the second major commercial use of space
- Photovoltaic cells convert sunlight to electricity, then this energy is converted to microwaves and beamed to Earth
- On Earth these receiver arrays convert microwave power to electrical energy
- SSP promises clean energy for Earth
- Remote parts of Earth can have power beamed to a local ground station allowing economic growth
- High latitudes are problematic
- Constructing these huge structures at geosynchronous orbit will promote robotic technologies valuable to working in hostile environments



## SSP Business Model

1975 NASA Study – Rockets  
35 years to “breakeven”

2004 M. Kellum Study – Space Elevator  
7 years to “breakeven”



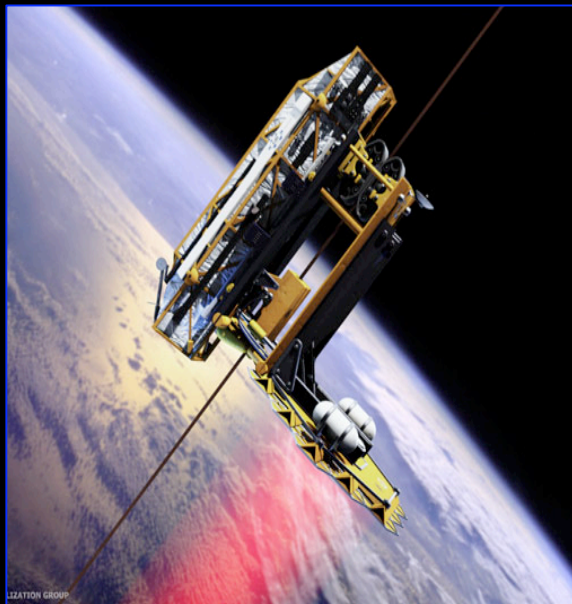
# The New World

- Space is close to us all the time
- Space is for everyone, not just the elite
- Space is a place to visit
- Space is a place in which to work
- Space is a place to make money
- Space is a place to experiment
- Other heavenly bodies are accessible
- Exploration and colonization is feasible
- Humans are safer from extinction by our conquest of space

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# Lunar Exploration

## • Apollo Program

- 1962 – 1972
- Precursor programs were Mercury and Gemini
- Development missions to test technology
- Lunar Orbit Rendezvous
- 6 successful moon landings (last one in 1972)
- 1 failed moon landing (Apollo 13) but crew returned safely
- Saturn V, LEM, Command and Service modules developed
- Cancelled prematurely by Nixon, 18, 19 & 20 never flew
- Cost \$135 B 2006 (\$25.4B 1969)

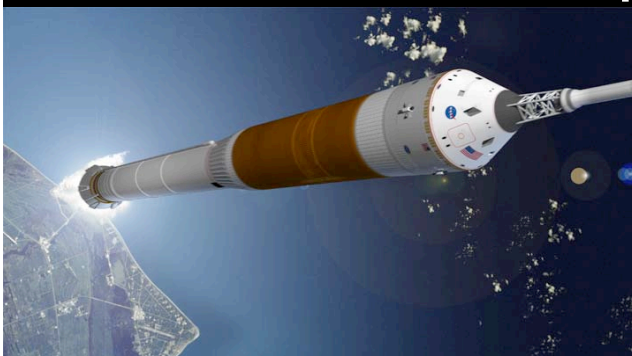
## • Space Exploration Initiative

- 1989
- ~\$270 Billion (1989) for Lunar exploration and operations over 34 years

## • Project Constellation

- 2004 - ?
- CLV & CEV being designed

# Lunar Exploration



## Project Constellation

Crew Launch Vehicle

Crew Exploration Vehicle



# Apollo Repeat?

## ● Apollo Design

- High-risk mission architecture (Apollo reliability was believed to be 50%)
- Sprint to the moon and back (leave no infrastructure although some equipment was left)
- Beat the Soviet Union there (exploration is secondary)
- Take pictures (PR)
- Bring back some souvenirs (moon rocks)
- Accept accolades

## ● Outcome

- Inspired a generation to become scientists and engineers and to expect manned space exploration to continue
- One mission provided know how to the next mission but no progress in terms of an infrastructure investment
- Soon after Apollo finished its mission of beating the Soviets to the moon, it was cancelled

## A SPACE ELEVATOR BASED EXPLORATION PROGRAM

### Principal Investigator:

Dr. Bradley C. Edwards

X Tech Corp.

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E-mail: brad\_edwards@yahoo.com

### Co-Investigators:

Dr. Hyam Benaroya

Rutgers University

Dr. Michael Duke

Colorado School of Mines

Dr. Hermann Koelle

Berlin Technical University

Dr. Bryan Laubscher

Los Alamos National Laboratory

Pam Luskin

Futron Corporation

Dr. David Raitt

European Space Agency - ESTEC

Ben Shelef

Spaceward Consulting

Dr. Paul Spudis

Spudis Lunar Resources

The Space Elevator Based Exploration Program will fully meet all of the goals set forth by President Bush and NASA Administrator O'Keefe.

Concept: Well-studied lunar systems are combined with an innovative transportation system to produce an optimal exploration program.

- Lunar Base: Optimized designs for base and CEVs

- Transport system

- The Space Elevator: Low-cost, high-capacity, definable development risk. 3000 tons/yr @ \$1B/yr operating cost

- CEV: Mature technology to limit risk and cost

- Evaluation Factors

- Safety : Efficient transportation allows for redundancy and overbuilt systems which provide safety

- Reliability: Few serious failure modes, failure mitigation quantifiable and achievable

- Affordability: 99% savings on transportation costs,

Total: \$68B from 2005 through 2023 for large initial base

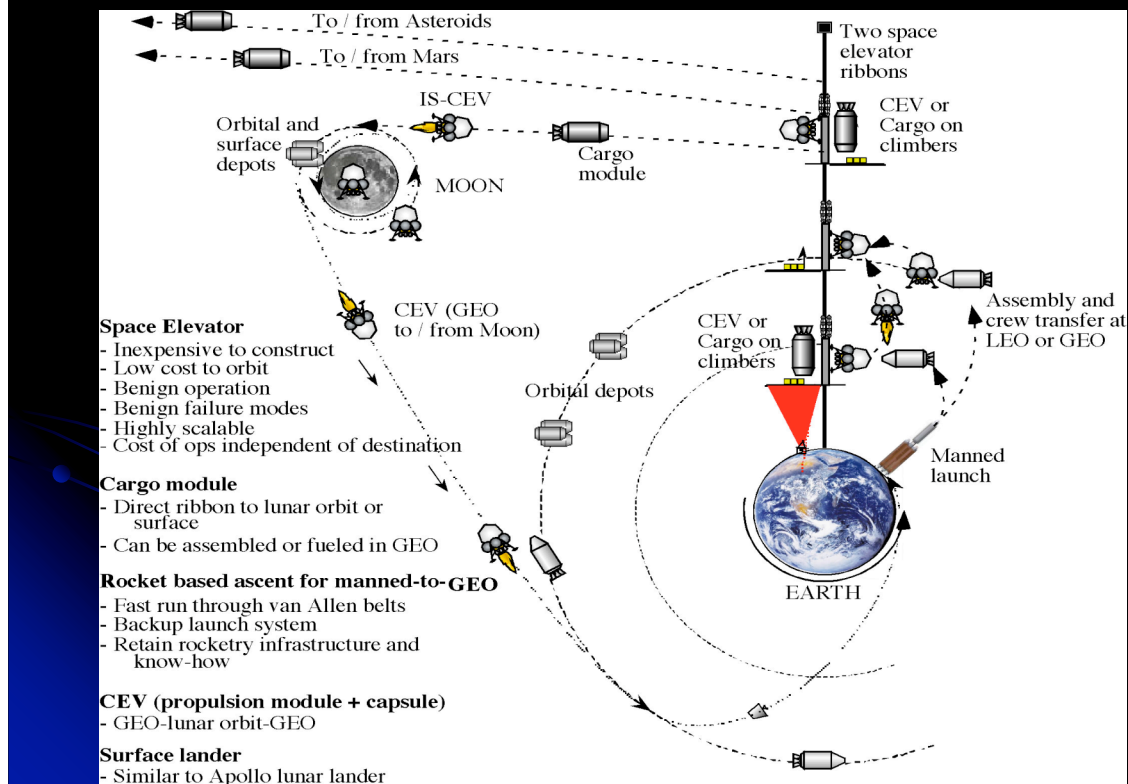
Peak: \$5B in 2020

- Sustainability: Low-costs, high-performance, public, international and commercial support probable

- Extensibility/Evolvability: System is immediately applicable to extending human exploration across solar system

- Risk Assessment: small initial development risk and low overall program failure risk

# Lunar Exploration



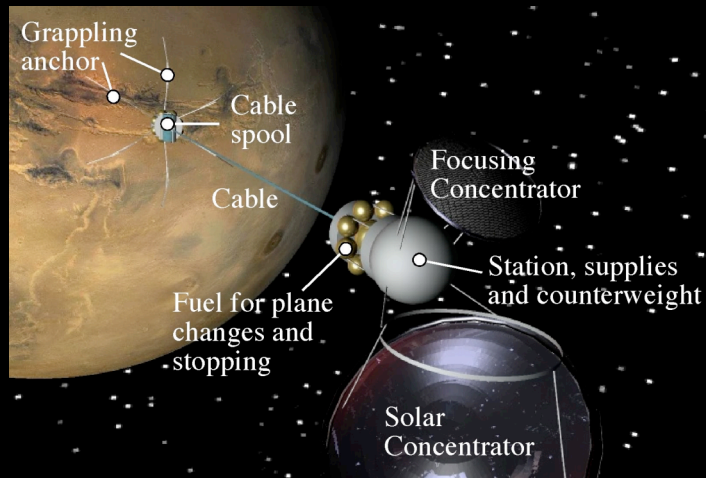
# Mars Exploration Plans

- 1989 SEI Program - NASA
  - Slightly modified Apollo era design mission, exploration and base operations for 34 years
  - ~\$270 Billion for lunar exploration
  - ~\$270 Billion over for Martian exploration
  - 1000 ton Spacecraft to Mars
- Mars Direct – Martin Marietta
  - In-situ resource utilization (ISRU)
  - 1000 tons → 87 tons
  - \$30 Billion
- 1993 Mars Design Reference Mission, NASA
  - Compromise between SEI and Mars Direct
  - \$55 Billion
- 2004 Project Constellation, NASA
  - Crew Exploration Vehicle
  - Crew Launch Vehicle

# Mars Exploration / Earth Elevator

## ● Earth Elevator

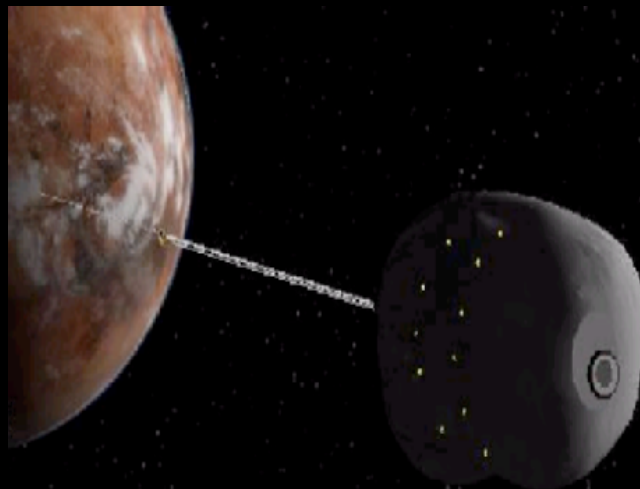
- Affordable, reliable robotic and manned exploration missions
- High capacity, low cost launches to Mars
- Possible to economically and reliably supply manned outposts and colonies
- Earth elevator throws a Martian elevator to Mars orbit



# Mars Exploration / Martian Elevator

## ● Martian Elevator

- Less massive and shorter than Earth elevator
- Deploys itself from orbit
- Save on aerobraking and landing hardware using Martian elevator
- Many interception altitudes are possible with a space elevator rendezvous
- Enables recycling of hardware between Martian and Earth orbit
- Enables capture of supplies from Earth and commerce from Mars to Earth





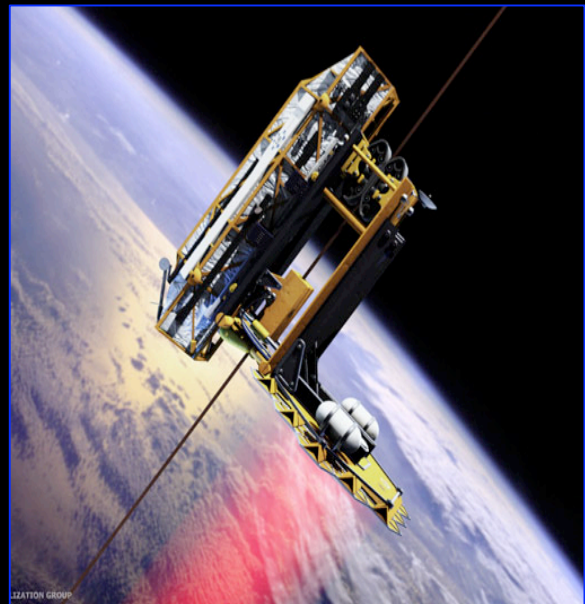
# Mars Exploration Recap

- Rocket
  - 72.5 kg on Earth to get 1 kg on Mars (rocket equation)
  - That means **\$725,000** / kg of cargo to Mars (with aerobraking)
  - Everything must survive violent launch environment
- Space Elevator
  - **\$3000** / kg (economy of scale)
  - Benign launch environment, except for radiation
  - Higher velocity trip to Mars possible
  - Launch infrastructure that supports our ambitions in space

## Directory Slide

### Topics to be covered:

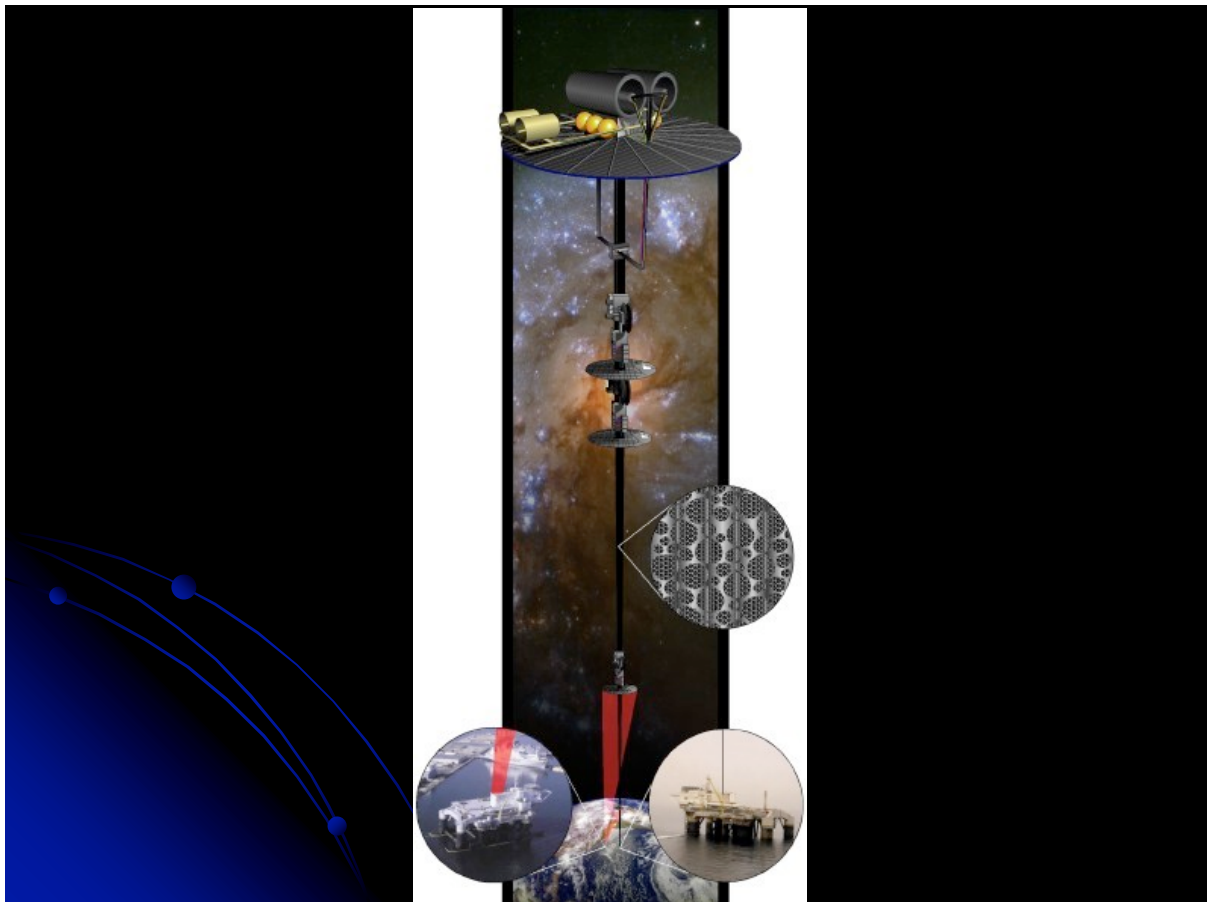
- Basic concepts
- Why the Space Elevator?
- Space Elevator History
- Space Elevator Design
- Space Elevator Challenges
- World Transformation
- Space Exploration
- **Conferences and Events**
- Philosophy
- Conclusion



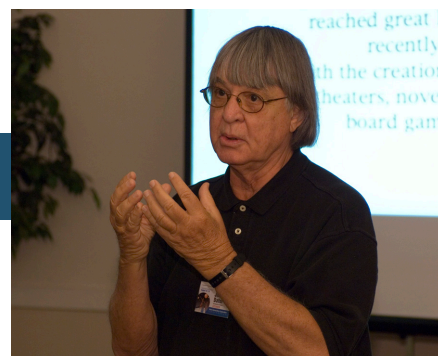
# Future Conferences

57<sup>th</sup> International Astronautical Congress,  
Valencia, Spain, October 2 – 6, 2006:  
[www.iac2006.com](http://www.iac2006.com)

Space Exploration 2007, 2<sup>nd</sup> Biennial Space  
Elevator Workshop, Albuquerque, NM March 25  
– 28, 2007: [www.sesinstitute.org](http://www.sesinstitute.org)



**Jim Dator**  
University of Hawaii



Jim Dator is Professor and Director of the Hawaii Research Center for Futures Studies, Department of Political Science and Adjunct Professor in the Program in Public Administration, the College of Architecture, and the Center for Japanese Studies, of the University of Hawaii at Manoa; Co-Chair, Space and Society Division, International Space University, Strasbourg, France; former President, World Futures Studies Federation; and Fellow and member of the Executive Council, World Academy of Art and Science. He also taught at Rikkyo University (Tokyo) for six years, the University of Maryland, Virginia Tech, the University of Toronto, and the InterUniversity Consortium for Postgraduate Studies in Dubrovnik, Yugoslavia. He is a Danforth Fellow, Woodrow Wilson Fellow, and Fulbright Fellow. He consults widely on futures of law, governance, education, and space.



**Comments about "Earth 3.0"**

Jim Dator

Next Generation Exploration Conference

August 17, 2006

My position can be  
dramatically stated:

Earth and everything on it  
is increasingly artificial.  
"Nature" no longer exists.



By "nature" I mean  
"processes and places  
entirely uninfluenced  
by human activities"

By "artificial" I mean  
entirely or largely  
made or influenced  
by human activity

All "once-natural" processes  
are now more or less  
"artificial"  
Meaning  
"influenced by  
human activities."

I am NOT saying  
that humans not part of  
nature,  
broadly understood.

Of course humans are  
a part of nature!

Neither am I saying that  
human influence on the rest  
of nature is somehow  
"unnatural".  
Since humans are part of  
nature,  
what we do must  
by definition be "natural."

Nonetheless, humans have  
substantially modified  
themselves  
and their environment  
from what they were  
when they first emerged  
as *homo sapiens*, *sapiens*  
roughly 50,000 years ago.

As a consequence,  
all once-natural processes  
now operate the way they do  
in part because of  
human activities.

We understand  
some once-natural processes  
  
individually fairly well  
some poorly  
some not at all  
and do not understand the  
totality of their interactivity  
at all.



We did not intend  
to impact these  
once-natural processes.

The impact is an  
unintended by-product  
of other human intentions,  
for the most part.

Nonetheless, we humans  
must assume responsibility  
for what we have done.

We must learn  
"to govern evolution"  
(title of a book written  
some time ago by  
Walter Truett Anderson)

Anderson says it is too late  
to say we should wait  
until we understand nature  
better  
before we undertake  
this obligation.

Such advice is like telling  
a 13 year old that  
she should wait a few years  
until she has gone to college  
before entering puberty  
so she will have the wisdom  
necessary to handle  
the changes  
of puberty better.

That may be true,  
but it is not helpful.

She WILL enter puberty  
and have to deal with it.

So also, humanity HAS  
created increasingly  
artificial environments and  
must learn how to invent  
and govern new ones.  
It is far too late for humans  
to decide they should  
stop and learn more.

So far, I have only focused  
on  
what humans and their  
once-natural  
biological environment.

But there is much more to it  
than this.

Humans live in completely  
artificial and increasingly  
virtual  
cultures and built  
environments  
that are entirely  
human inventions.



While human capability  
of speech depends on  
biophysical properties  
unique to humans,  
human spoken languages  
are entirely artificial,  
while written languages are  
even more obviously so.

The human ability to  
imagine and describe  
entirely imaginary worlds

and eventually to write,  
depict, enact, and  
otherwise record them  
reached great heights  
recently  
with the creation first of  
theaters, novels and  
board games

then with the creation of  
radio, movies,  
and television,  
and now with  
virtual realities  
and interactive  
electronic video games.

More people spend time  
in, worrying about, and  
interacting with  
imaginary and  
artificial people  
and situations  
than with those in the  
"real world" around them.

The very idea of modern  
"democratic government"  
also assumes that humans  
are not at the mercy of  
nature, gods, or kings,  
but can make up and follow  
their own rules and so  
govern themselves  
individually and collectively.

The emergence of  
genetically-modified or  
engineered humans and  
posthumans as well as of  
artificially-intelligent beings  
and cultures  
is also expected  
over the 21<sup>st</sup> Century.

The Search for  
Extra-Terrestrial Intelligence  
and the field of Astrobiology  
suggests the existence of  
forms of life and intelligence  
that did not originate on  
Earth  
which humans might  
eventually encounter.



For more discussion about  
this,  
and an extensive  
bibliography, see

<<http://www.futures.hawaii.edu/dator/artificiality/DatorAssumeRose.html>>

Humans on Earth  
need all the help  
they can get  
to learn how  
"to govern evolution"

Space research  
can help them

There has been research  
and experiments  
by space agencies,  
industries, and others  
about creating  
viable environments  
for humans in space.

**Chris McKay**  
NASA Ames Research Center



Dr. Christopher P. McKay, Planetary Scientist with the Space Science Division of NASA Ames. Chris received his Ph.D. in AstroGeophysics from the University of Colorado in 1982 and has been a research scientist with the NASA Ames Research Center since that time. His current research focuses on the evolution of the solar system and the origin of life. He is also actively involved in planning for future Mars missions including human exploration. Chris been involved in research in Mars-like environments on Earth, traveling to the Antarctic dry valleys, Siberia, the Canadian Arctic, and the Atacama desert to study life in these Mars-like environments. His was a co-I on the Titan Huygen's probe in 2005, the Mars Phoenix lander mission for 2007, and the Mars Science Lander mission for 2009.





## Life on Mars: Past, present, and future

Chris McKay

NASA Ames Research Center

cmckay@mail.arc.nasa.gov

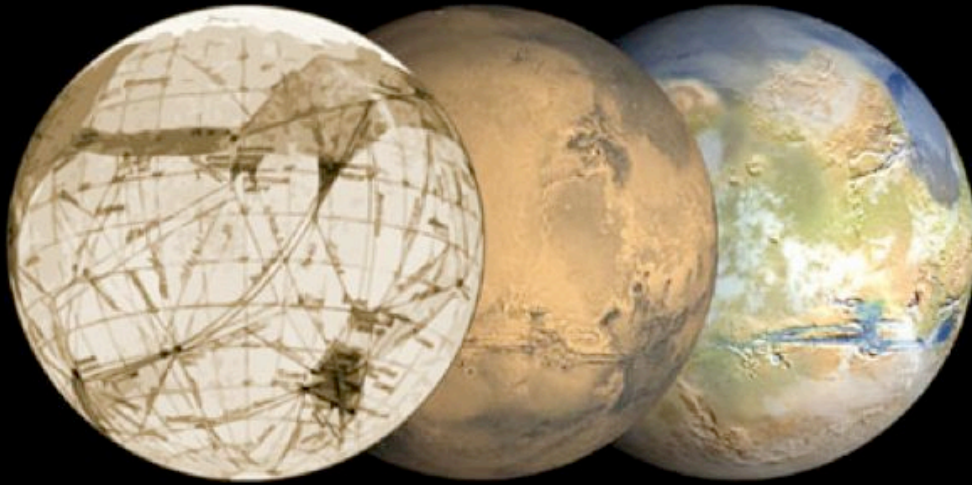
This talk is a compilation based on the work of many colleagues over many years. My thanks and acknowledgements to all of them

## Why is Life on other Worlds Interesting?

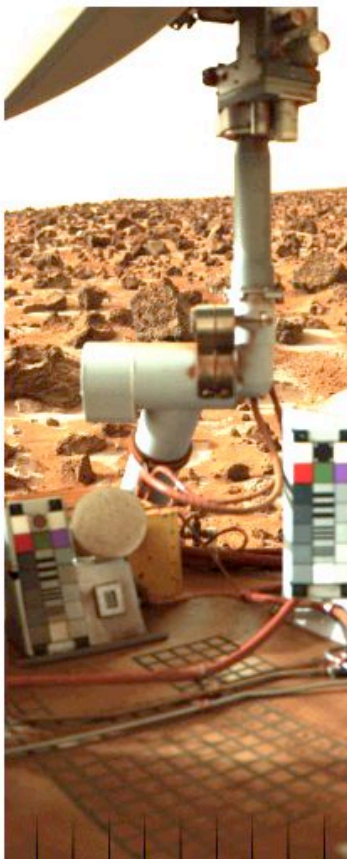
- The possibility of a second genesis of life:
  - ⇒ comparative biochemistry
  - ⇒ life is common in the universe (yeah!)
- Information about the early planetary environment
- Relevant to the origin of life on Earth



## Why Mars?



Evidence for past liquid water  
Presence of an atmosphere with  $\text{CO}_2$  &  $\text{N}_2$   
Potential for preservation of evidence of life



Viking:

water frost on Mars

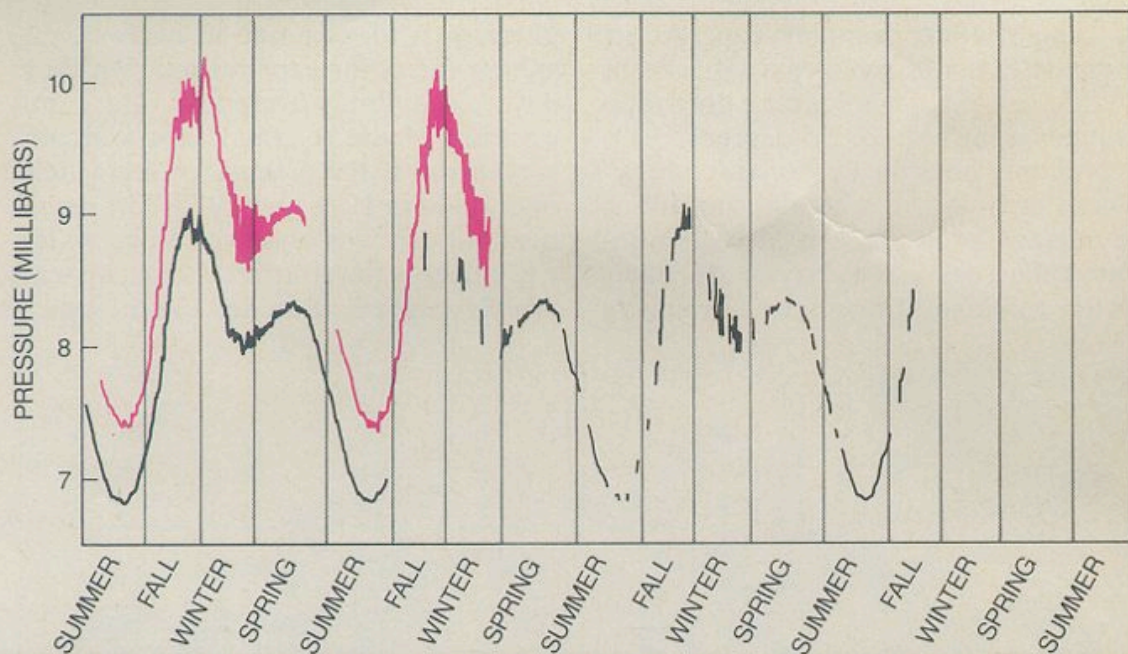
water flowed on the surface



## Composition of the Martian Atmosphere

- Carbon Dioxide (CO<sub>2</sub>) 95.3%
- Nitrogen (N<sub>2</sub>) 2.7%
- Argon (Ar) 1.6%
- Water Vapor (H<sub>2</sub>O) 0.03% - 0.1%  
(saturated in places)
- Oxygen (O<sub>2</sub>) 0.13%
- Carbon Monoxide (CO) 0.07%

Pressure at the two Viking lander sites (Earth = 1013)

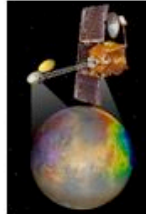


# Current Mars Missions

- Mars Global Surveyor



- Mars Odyssey



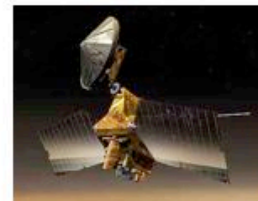
- Mars Exploration Rovers



- Mars Express

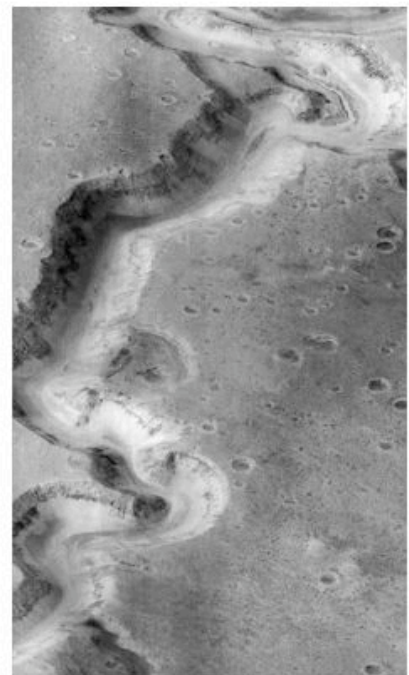


- Mars Reconnaissance Orbiter



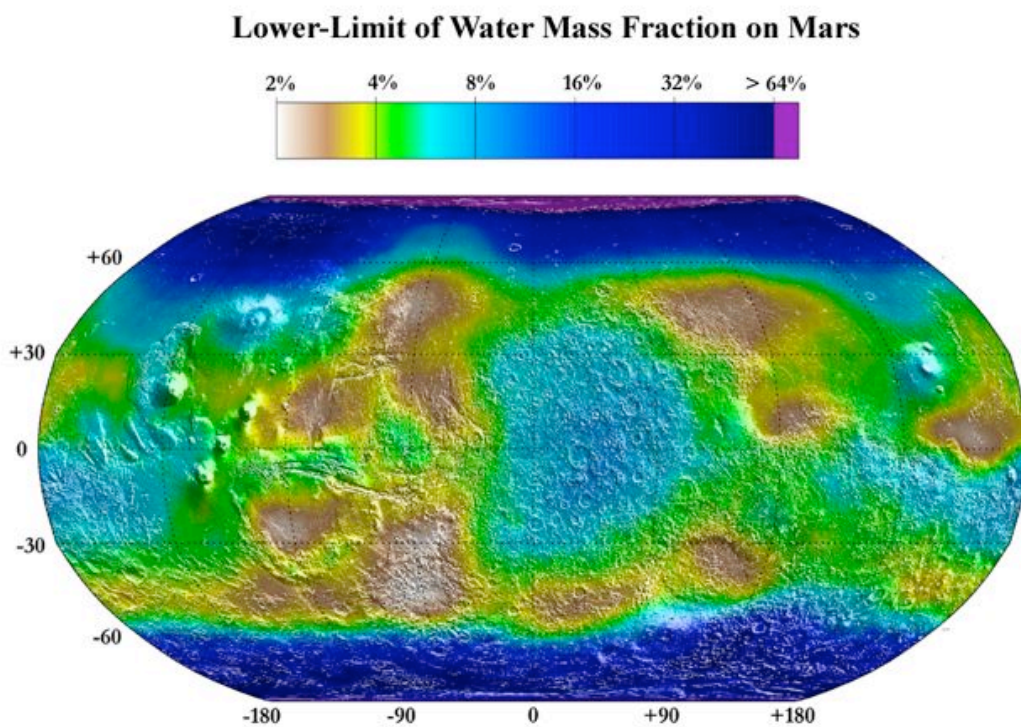
Mars Global Surveyor  
&  
Mars Express

Evidence for  
water flow on  
Mars



Nanedi

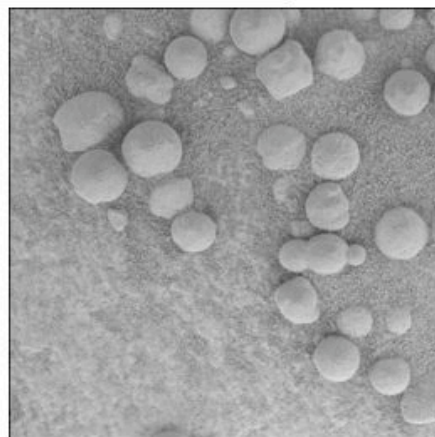
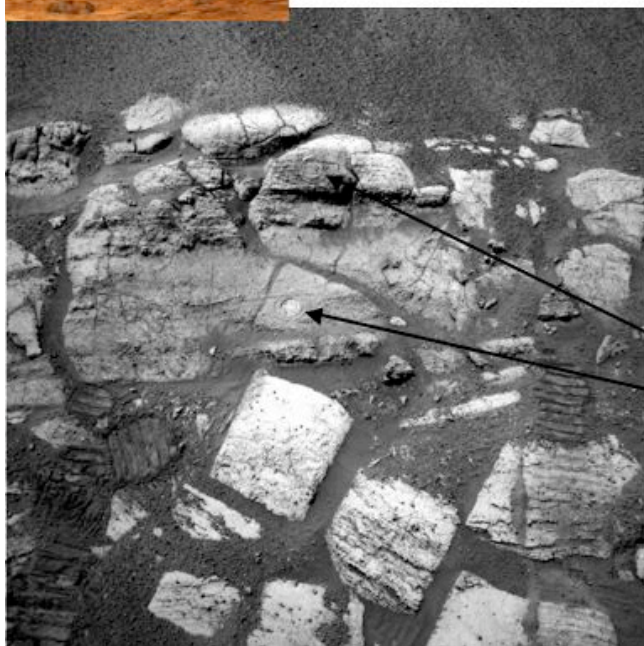




Minimum estimated water mass fraction in the top 1 meter of the martian surface from GRS on Mars Odyssey. <http://grs.lpl.arizona.edu/>



### Evidence for Water at Meridiani Planum

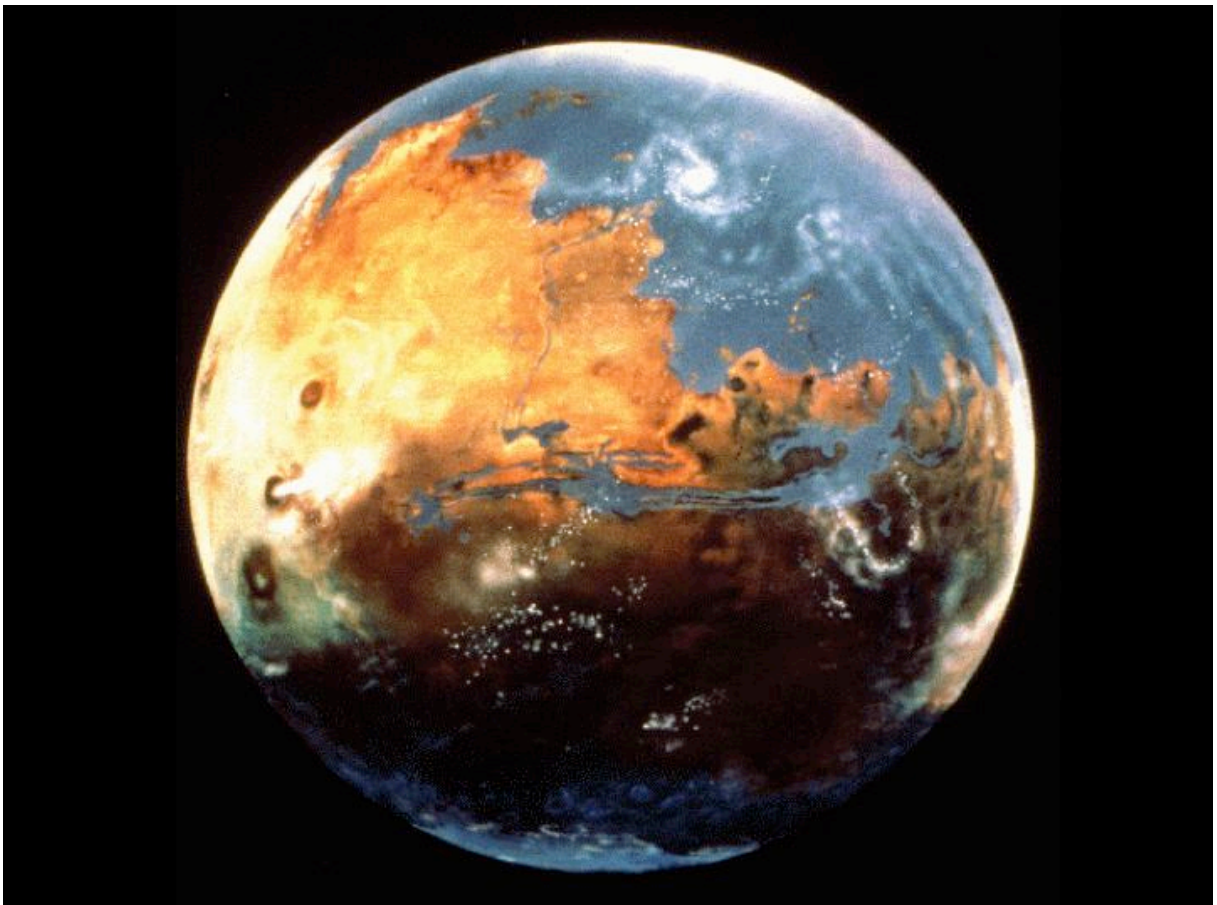


'Blueberries' are  
hematite concretions

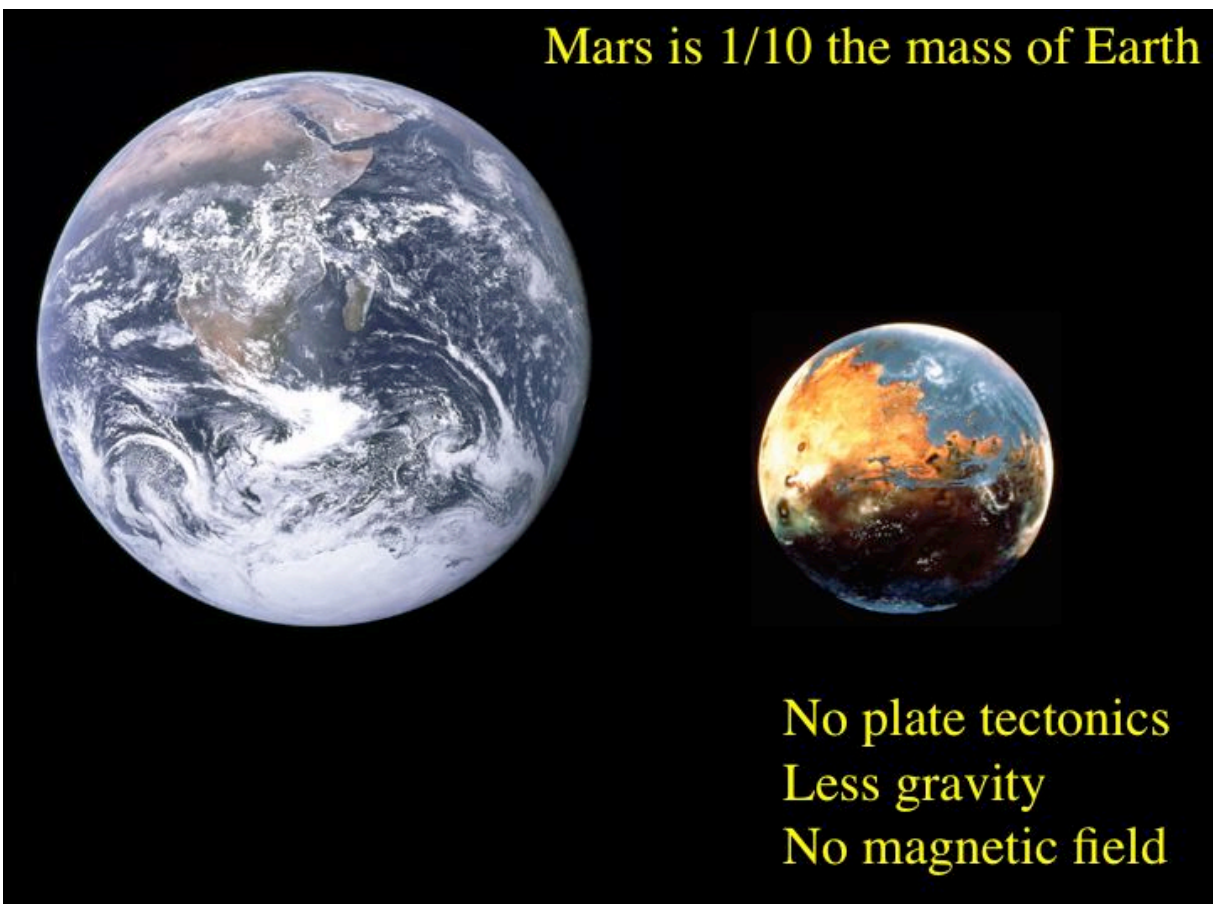
More salt  
Less salt

Layering consistent with water.



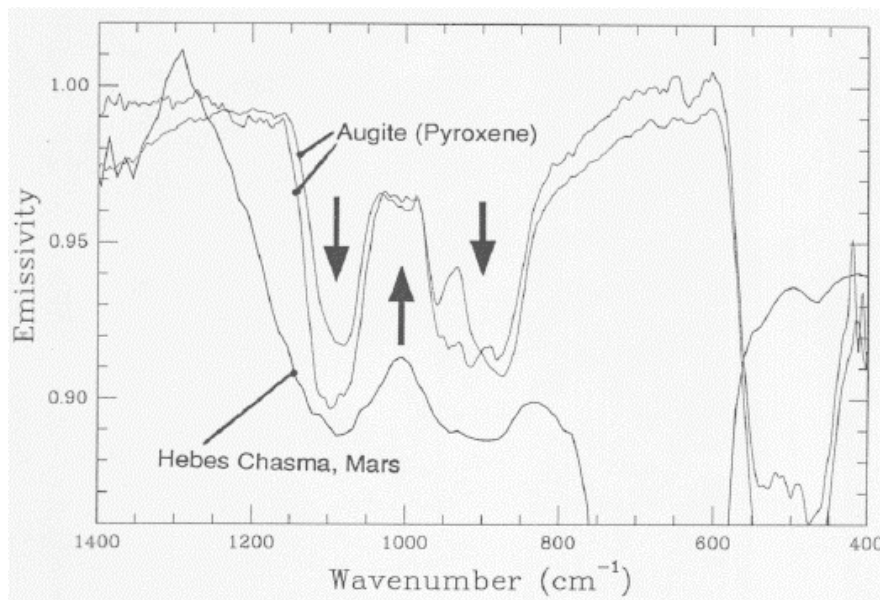
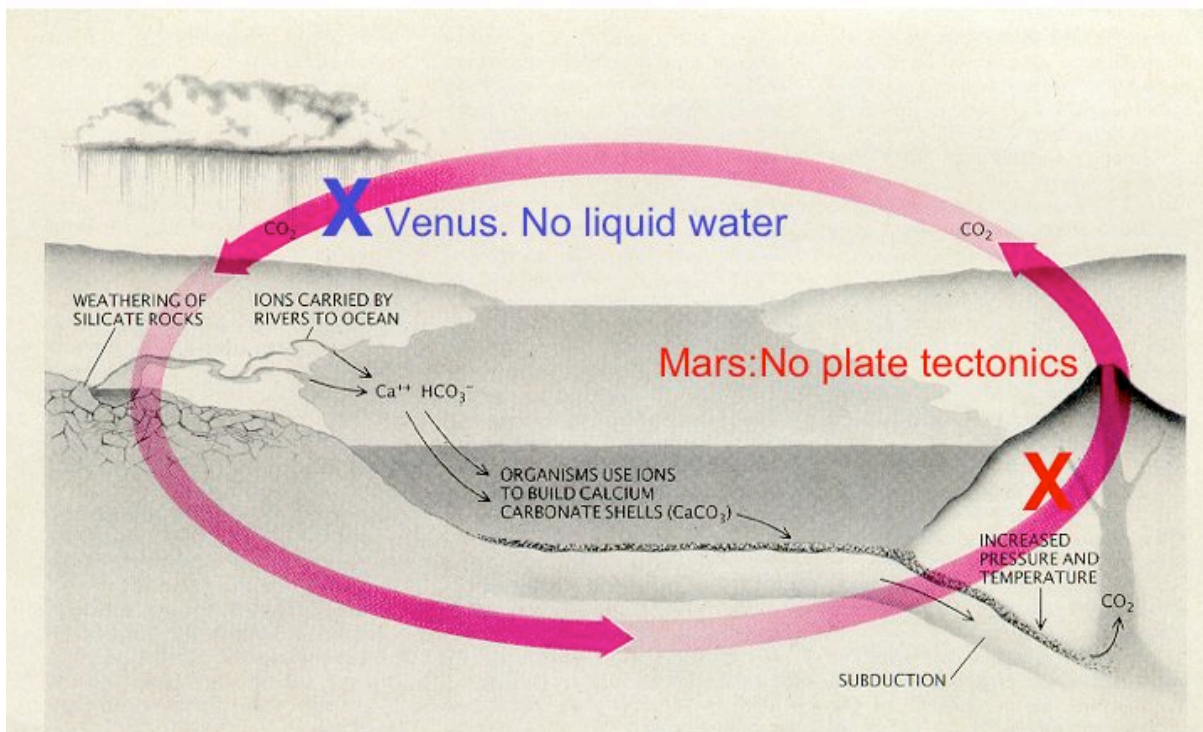


Mars is 1/10 the mass of Earth



No plate tectonics  
Less gravity  
No magnetic field

## Venus and Mars lack the complete cycle



Thermal  
Emission  
Spectrometer

indicates a dry  
cold world.

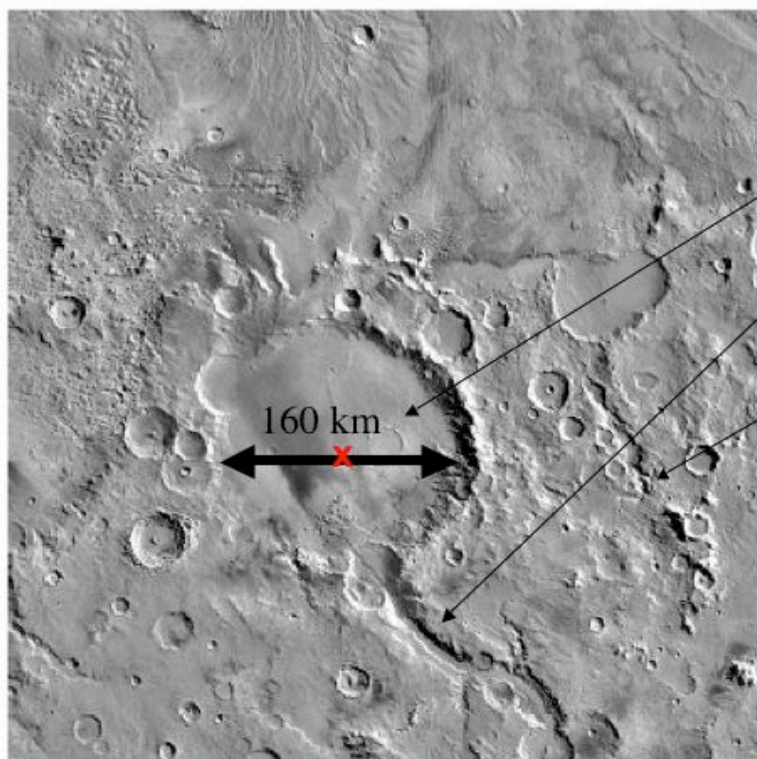
From the *TES top 25 Science* results:

Unweathered volcanic minerals (pyroxene, feldspar, and minor olivine) dominate the spectral properties of martian dark regions. Conversely, no evidence has been found for weathering products above the TES detection limit. This lack of evidence for chemical weathering of the martian surface indicates a geologic history dominated by a cold, dry climate in which mechanical weathering was the dominant form of erosion.



# When Mars was wet it was cold

- Evidence of very low erosion:  
 $< 10^{-9}$  m/yr, compare to dry valleys  $10^{-6}$  m/yr
- Sporadic distribution of valley features
- Unweathered basaltic surface minerals
- Climate modelers have difficulty getting surface temperatures above  $0^{\circ}\text{C}$ .
- No massive surface carbonates detectable by remote sensing.

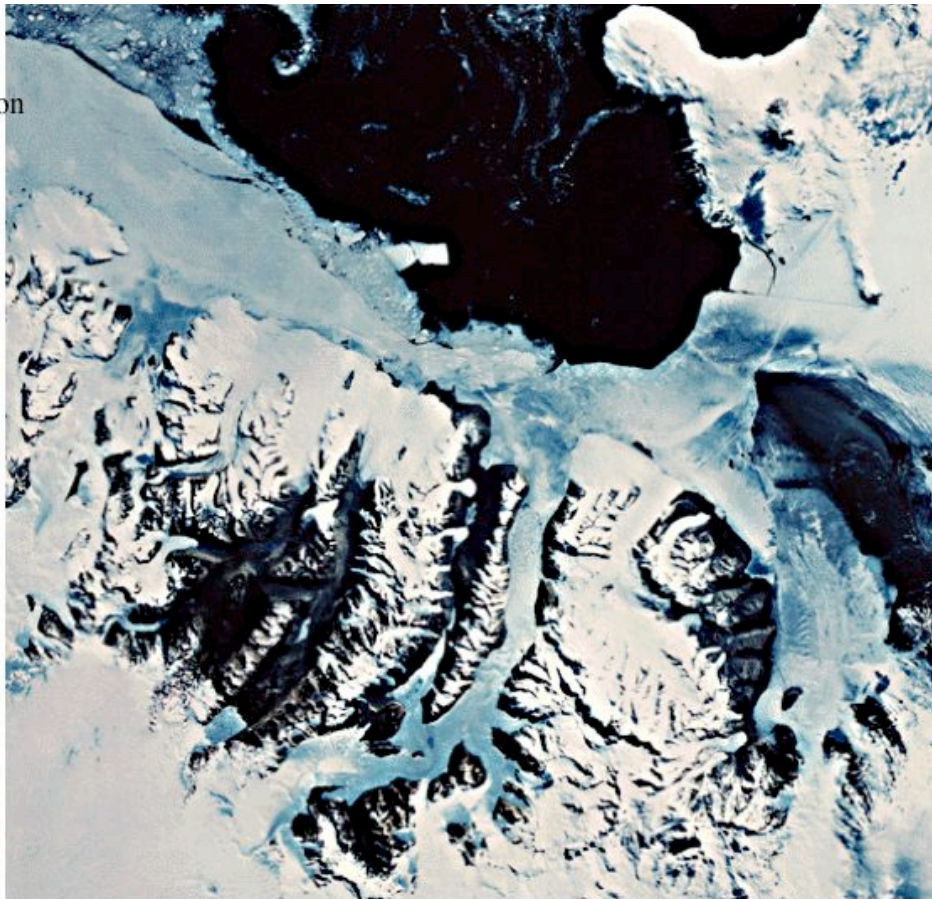


## Gusev Crater

- Large crater lake
- Large river
- Preserved craters inconsistent with rain

### The Dry Valleys

- Largest ice-free region in Antarctica
- Temperatures:  
-20°C average  
+10°C maximum
- 1-2 cm equivalent  $H_2O$  as snow
- Pressure well above triple point of  $H_2O$



### Lake Vanda and the Onyx River in the Antarctic dry valleys

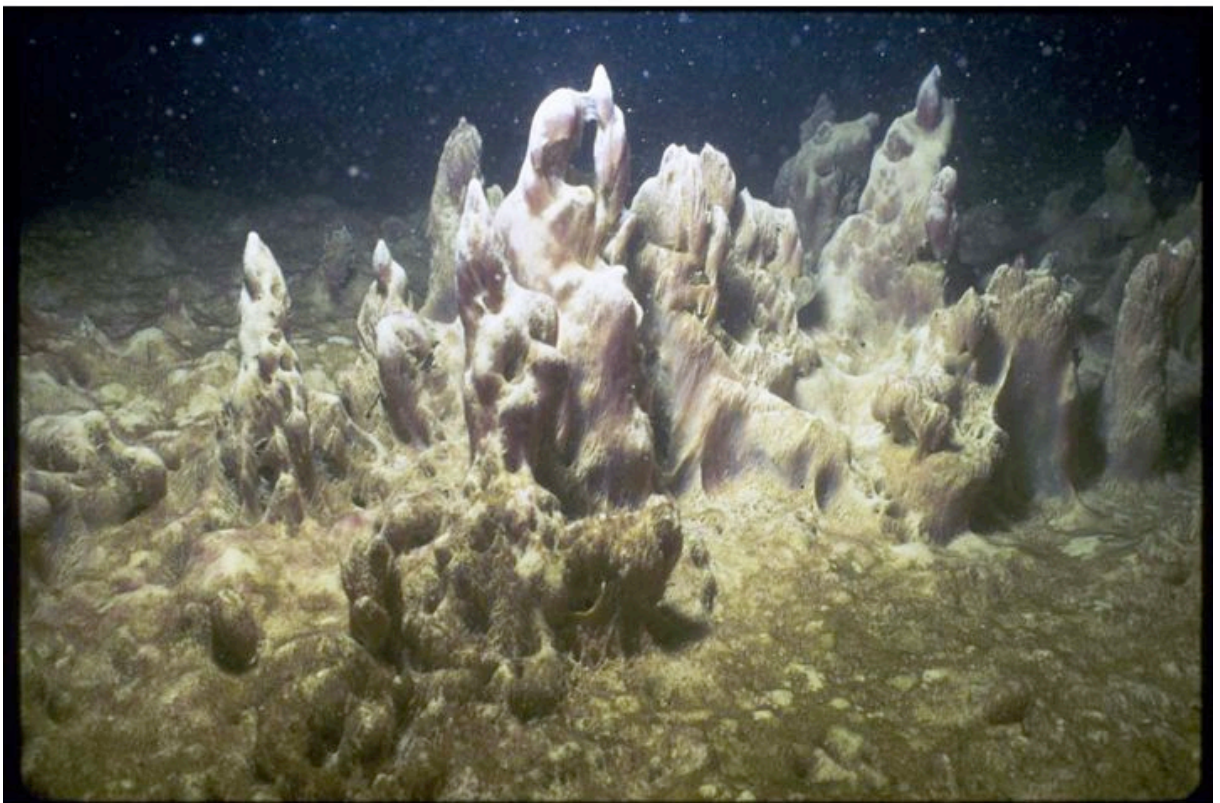
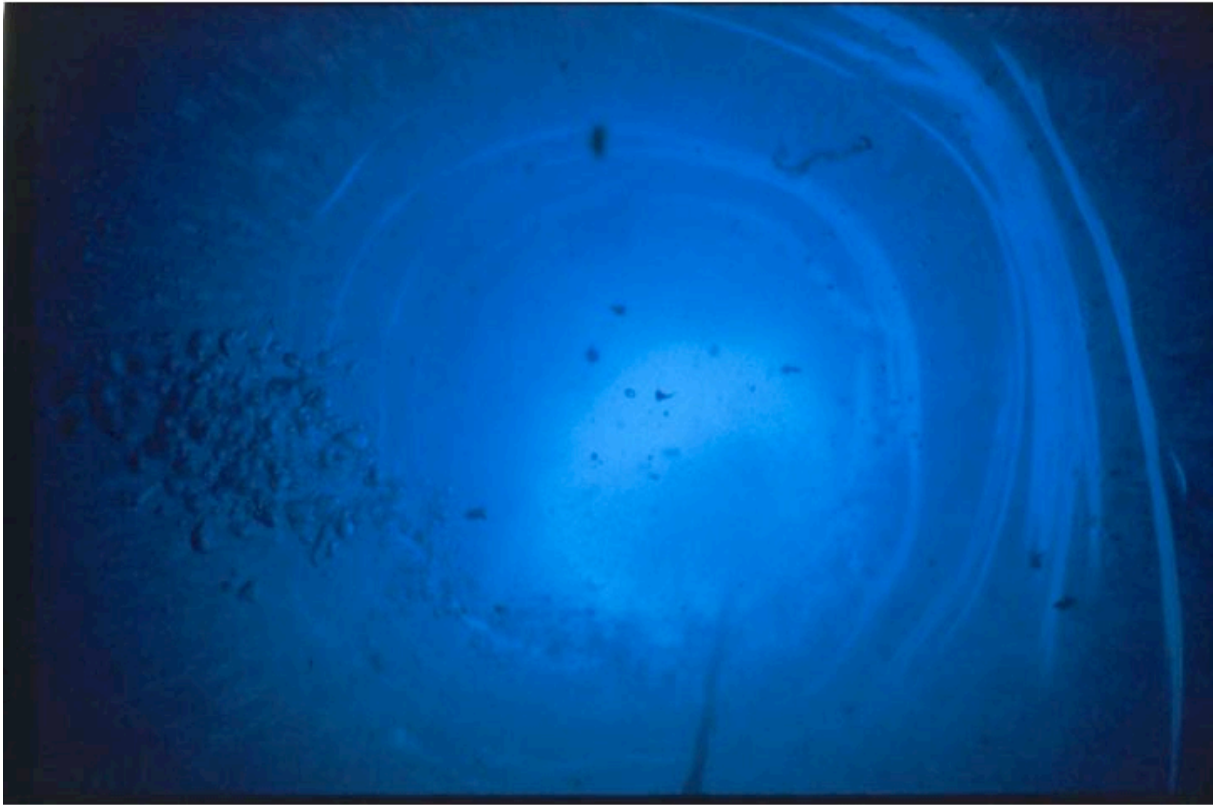




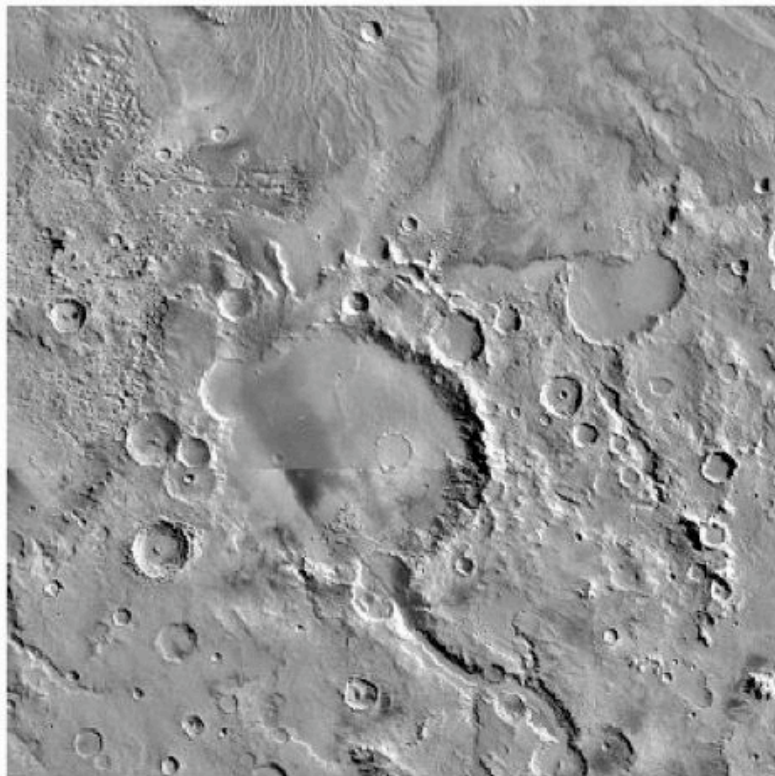
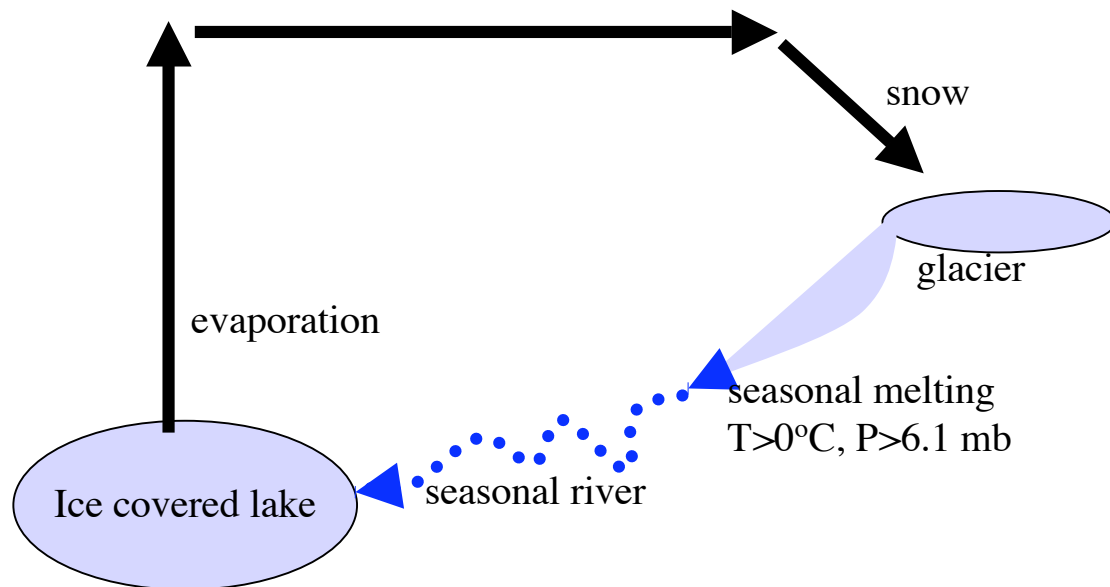








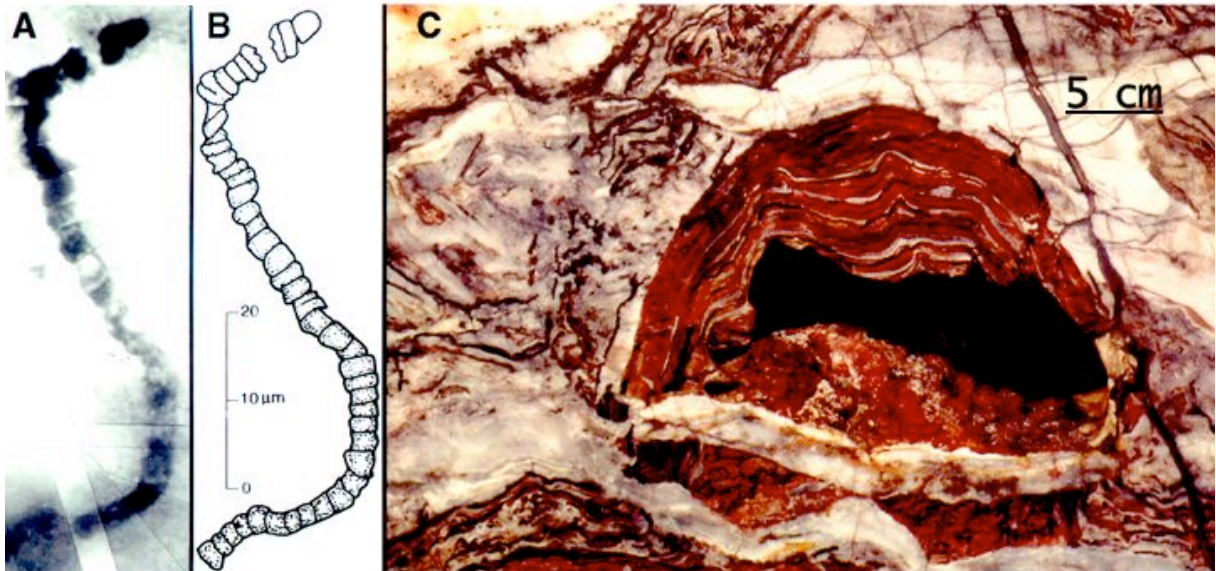
# Snow-based hydrological cycle





## Oldest (probable) fossil on Earth: 3.5 Gyr old

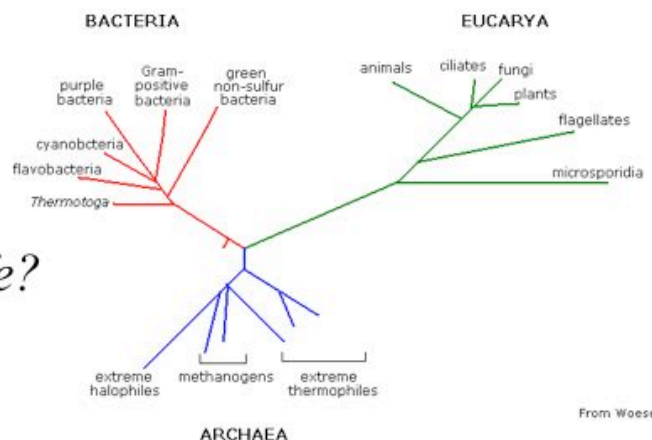
courtesy of J.W. Schopf



## Fossils are not enough

- Fossils tell us that there was life on Mars
- But not the nature of that life or its relationship, if any, to life on Earth

*Is martian life  
on the tree of life?*



From Woese, 1987



## Fossils are not enough for a forensic investigation.

### Possible Sources:

- Viable spores in the soil
- Extant subsurface life
- Organisms preserved in amber or salt
- **Organisms preserved in permafrost** ←





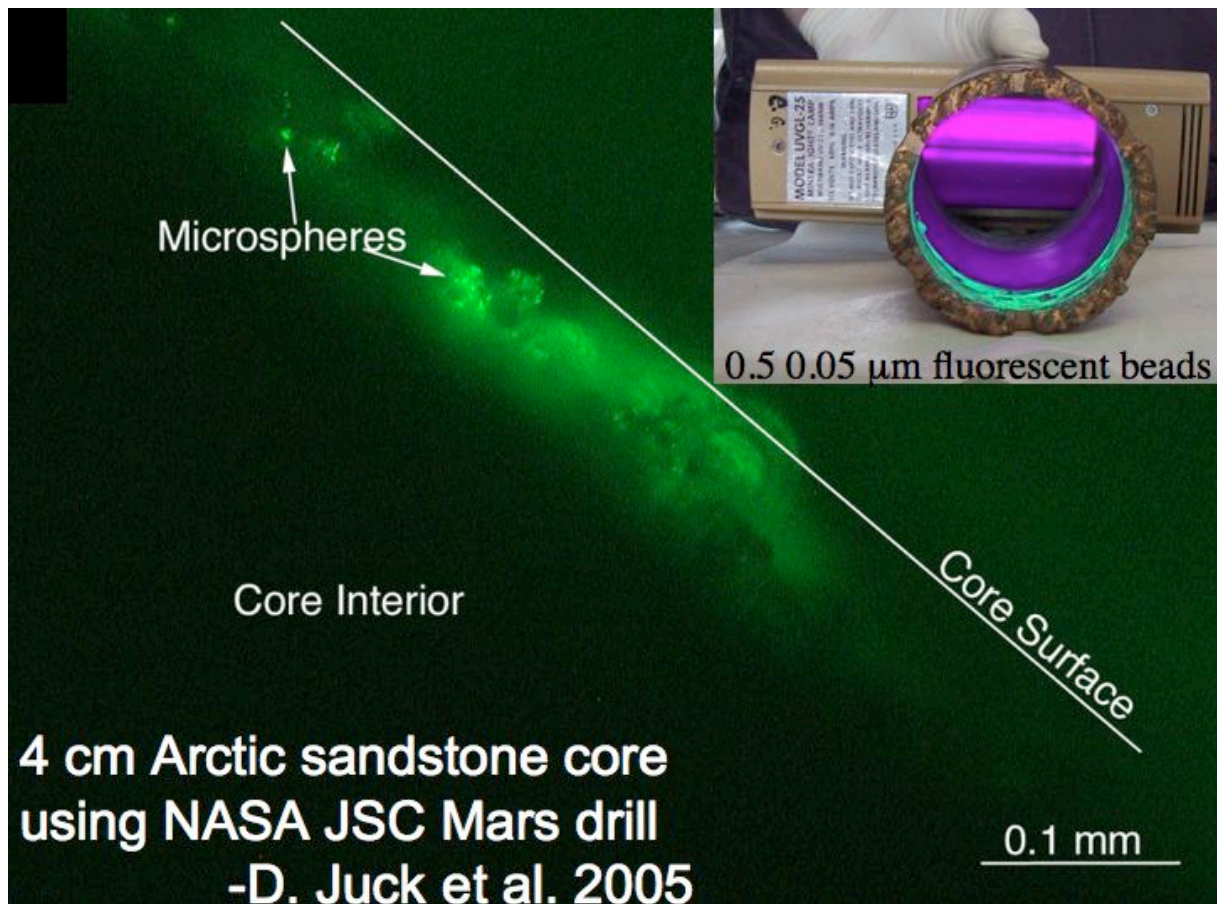
Permafrost in Siberia: 3.5 Myr old and contains viable bacteria



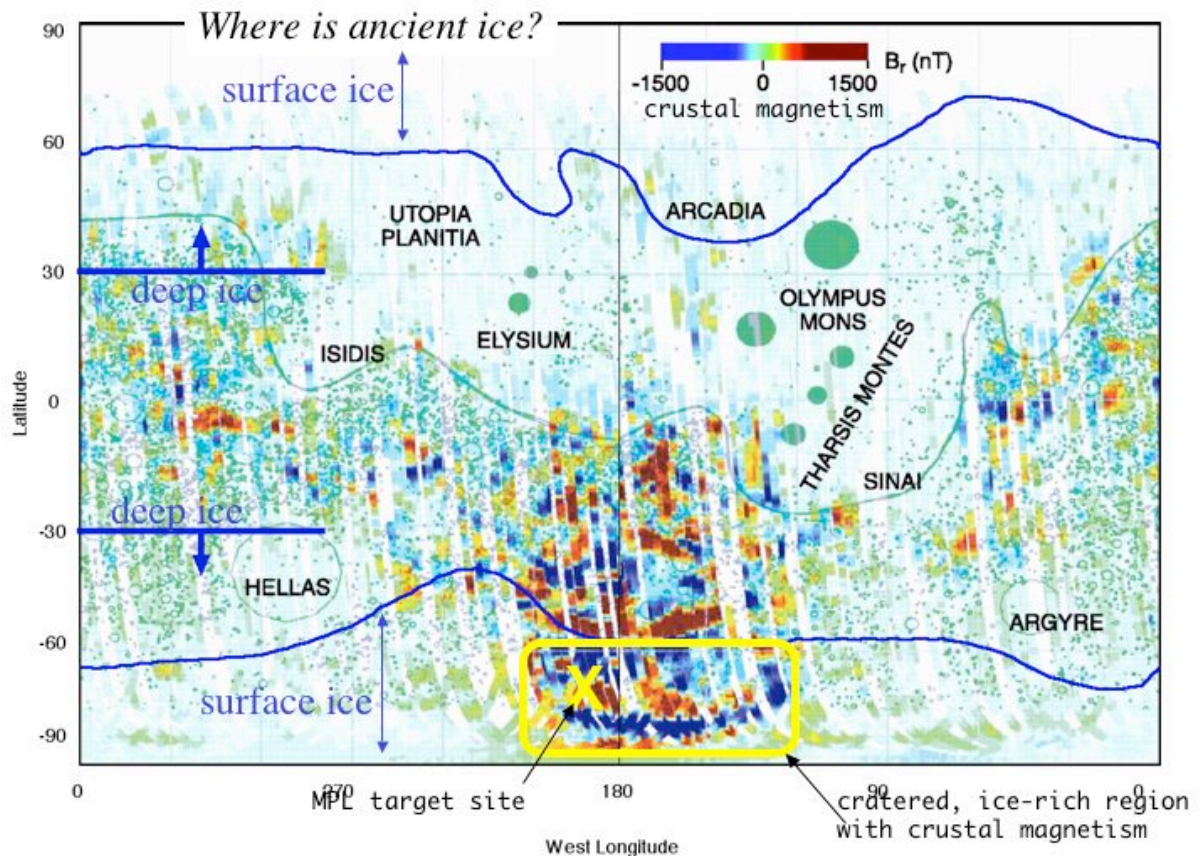
Beacon Valley, Antarctica: Here there may be 8 Myr old ice;  $-25^{\circ}\text{C}$   
This ice contains viable bacteria and may be the oldest ice on Earth.











## Limits on long term dormancy

- kT: Thermal decay:  $\sim e^{-\Delta E/kT}$   
 racemization of amino acids  
 degradation of organic material  
*not important on Mars, -70°C*
- eV: Radiation from crustal U,Th, K  $\sim 0.2$  rad/yr  
 lethal dose for *Deinococcus radiodurans* in 100 Myr  
*on Mars hundreds of lethal dose over 3.5 Gyr*
- Its dead, Jim

Phoenix launches in 2007



If we find organic material  
on Mars (or Europa) how  
can we tell if it was ever  
alive?

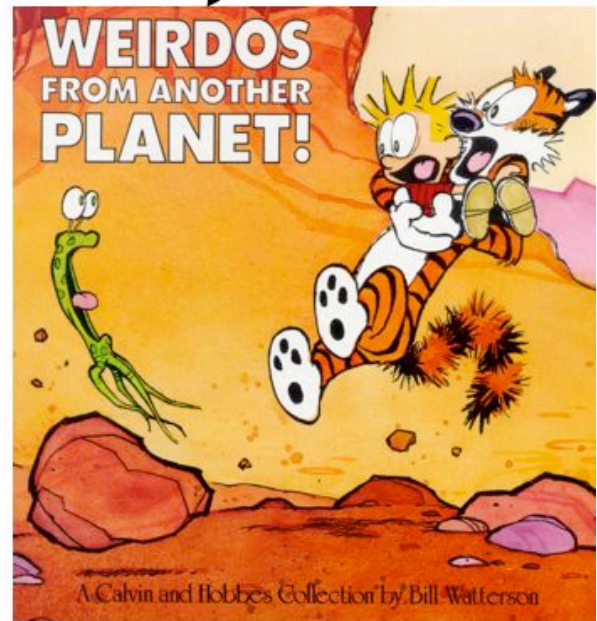
If its like us then easy, less interesting  
If its alien then hard, but interesting



## How do we recognize alien life?



we'll know it when we see it!

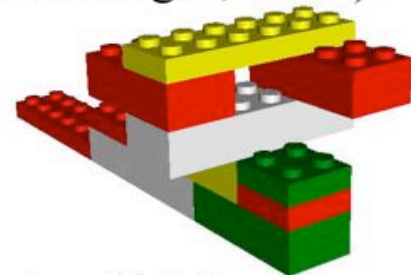


use a tricorder!

## The Lego® Principle

•Biology is largely built from on a small number of components (Lehninger, 1975):

- 20 L amino acids
- 5 nucleotide bases
- few D sugars, etc.

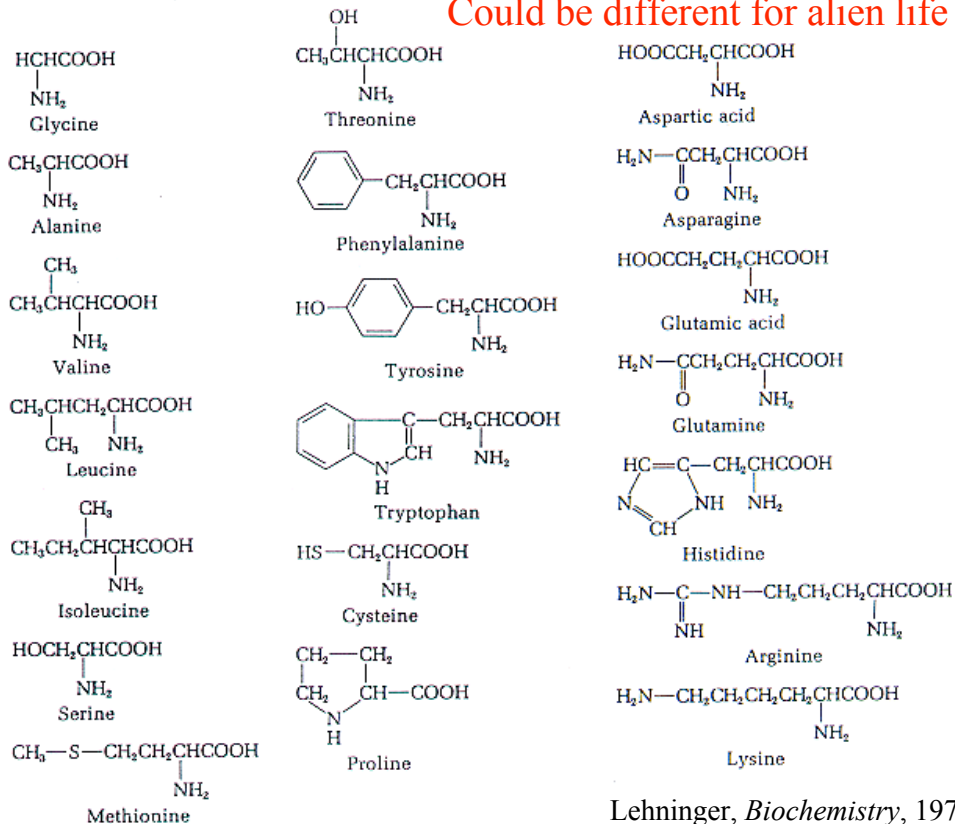
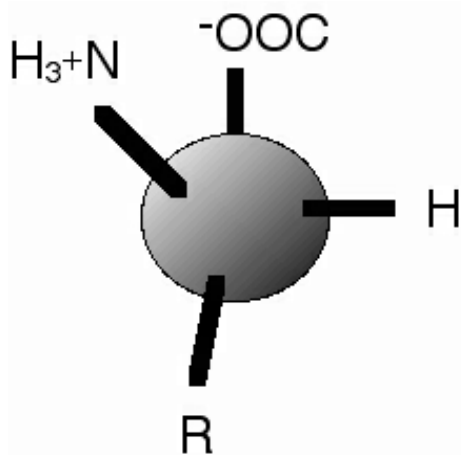


•Likely a common property of biology (and mass-produced children's toys) throughout the universe.

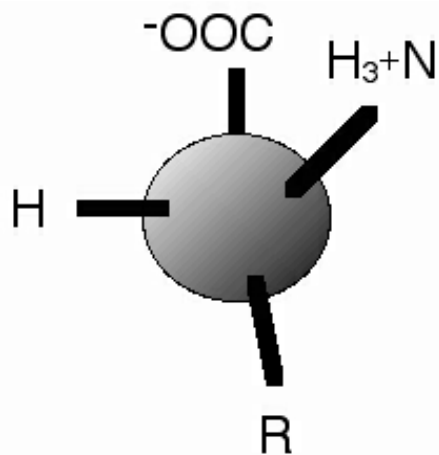
McKay 2004 *PLoS Biol* 2(9)1260-12623

## The Primordial Biomolecules

The amino acids (in un-ionized form)

Lehninger, *Biochemistry*, 1975 page 21

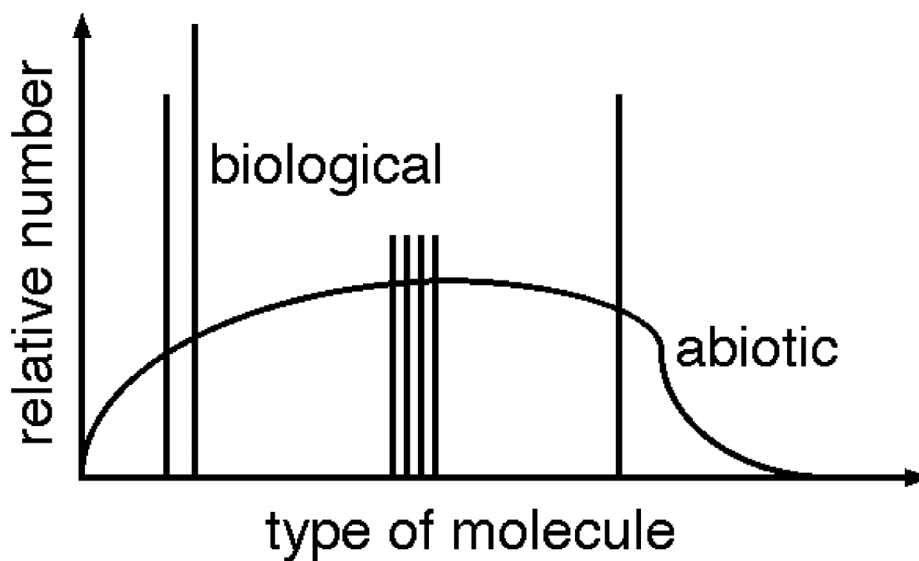
L - amino acids  
used by life



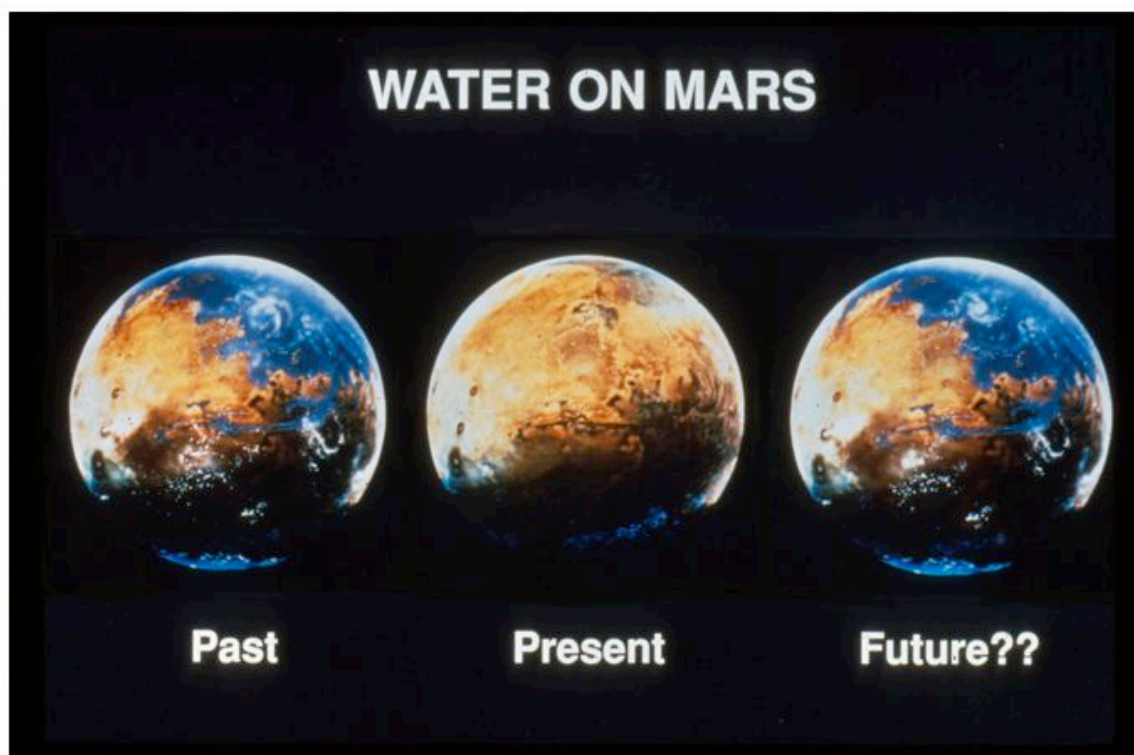
R - amino acids  
not used by life



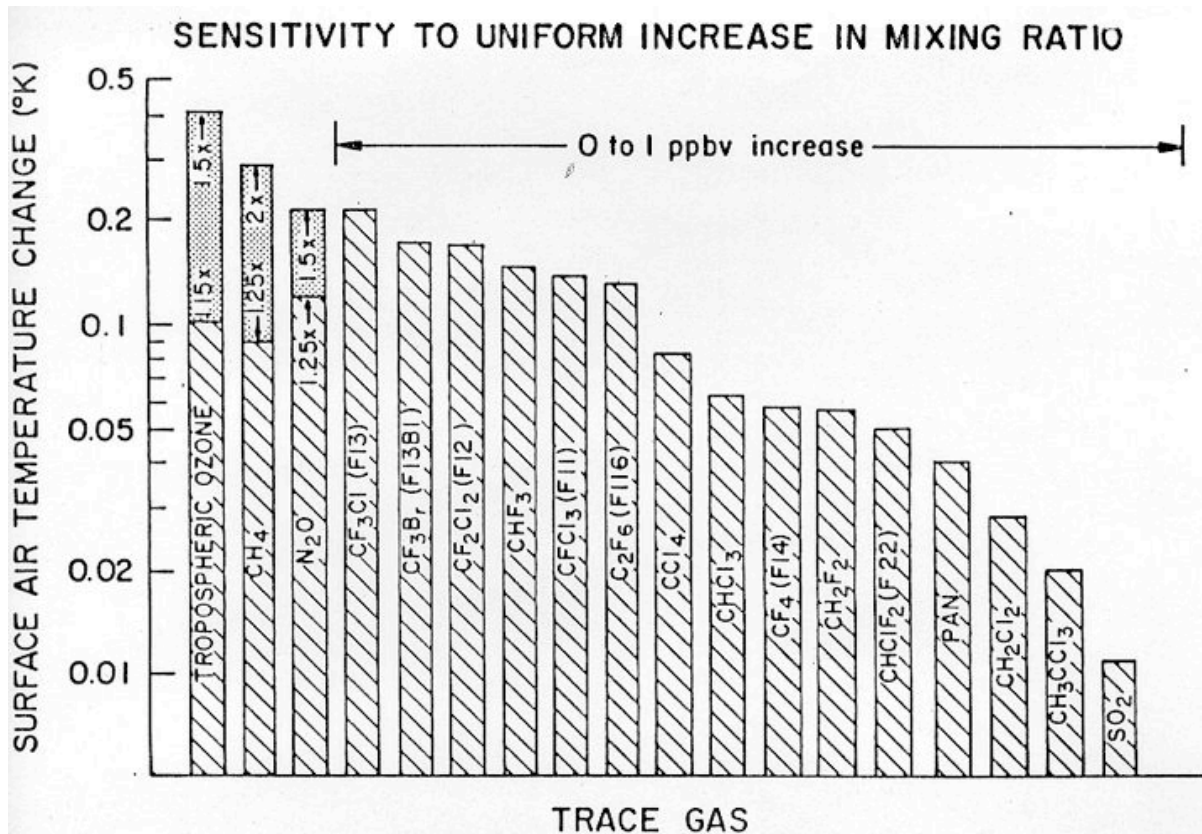
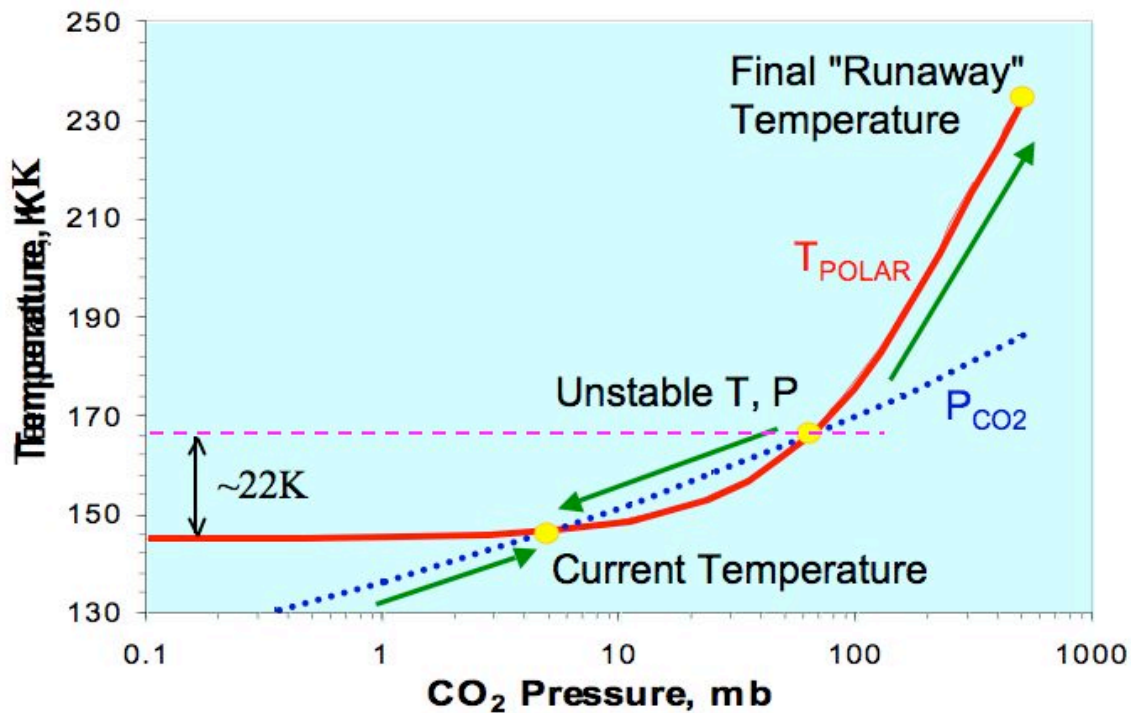
Abiotic distributions are smooth  
Biotic distributions are spiked



McKay 2004 *PLoS Biol* 2(9)1260-12623

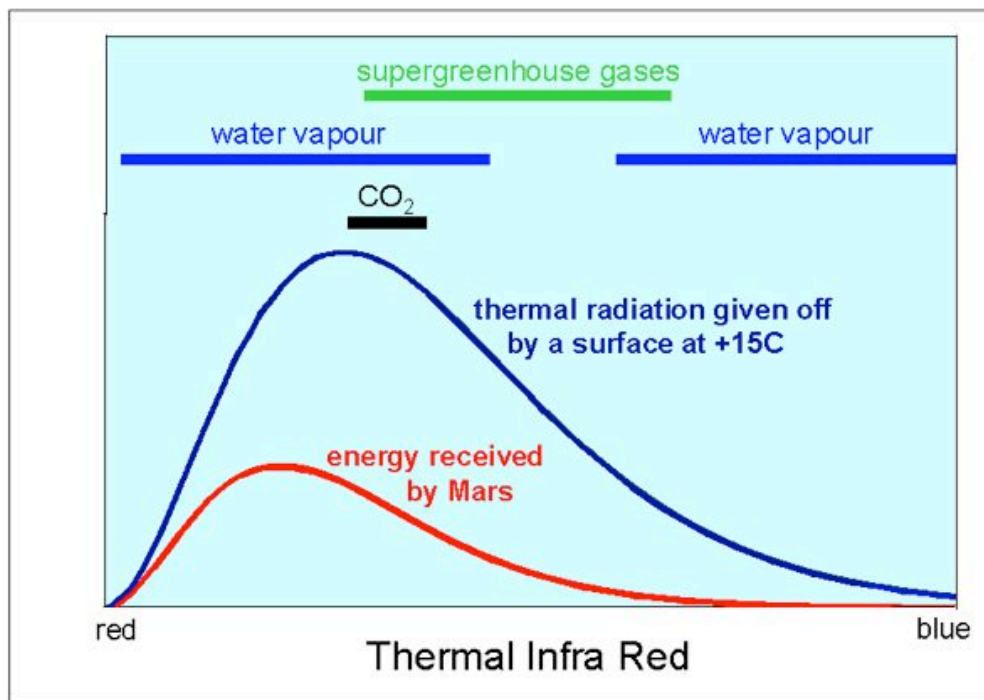


## How much warmer?

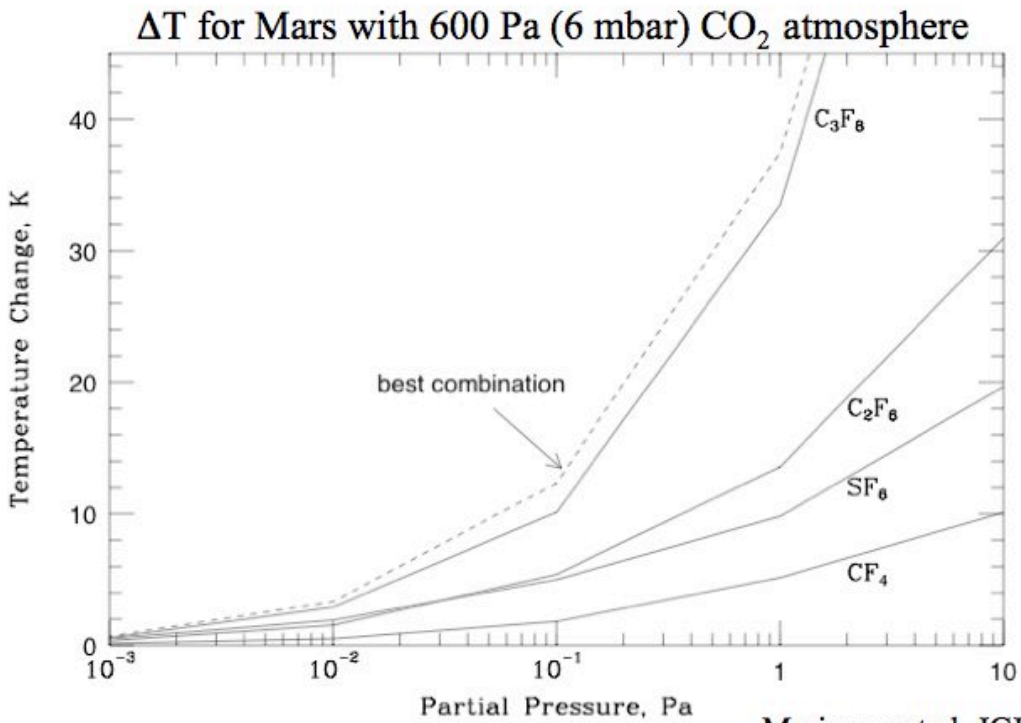


from Ramanathan et al. J. Geophys. Res. 1988.

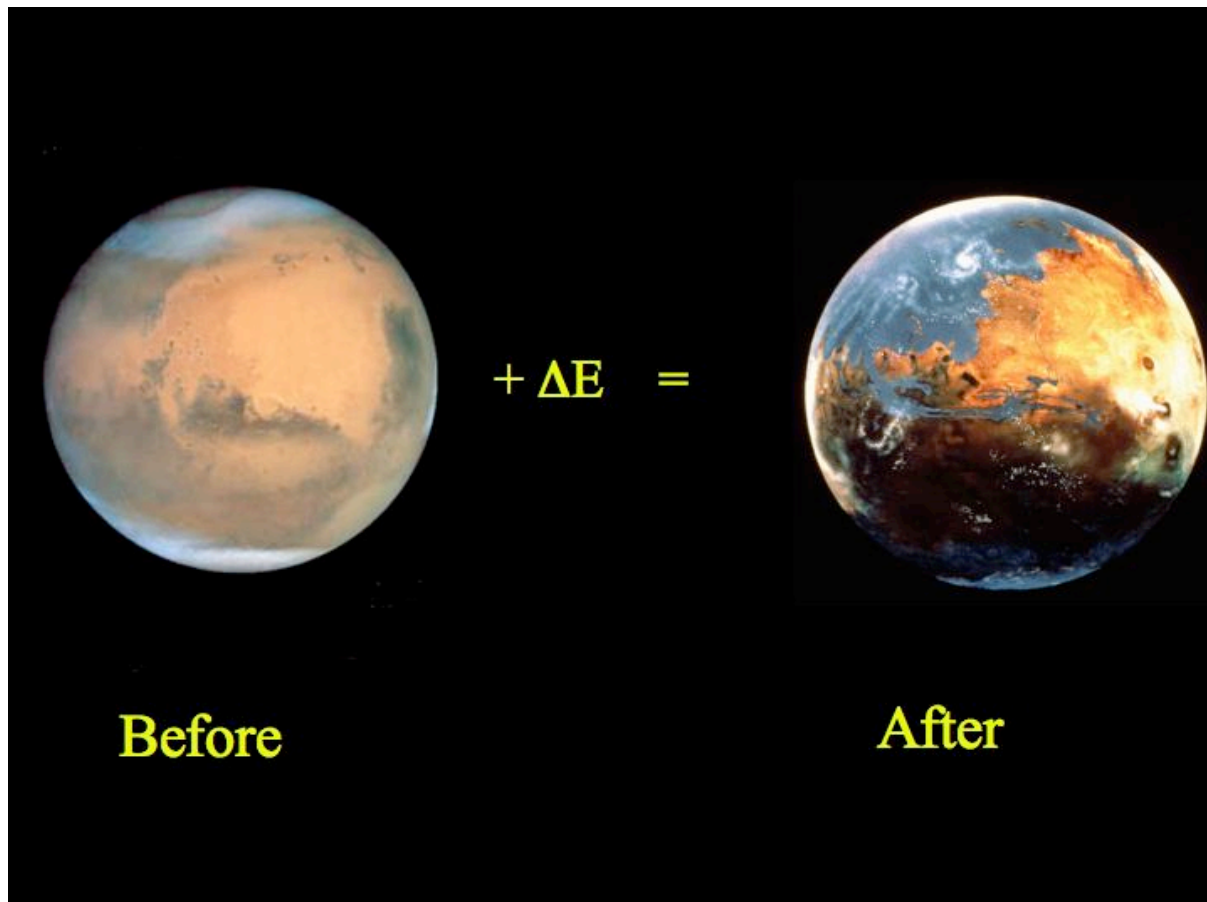
## The Greenhouse Gases Blanket



# Results



Marinova et al. JGR 2005



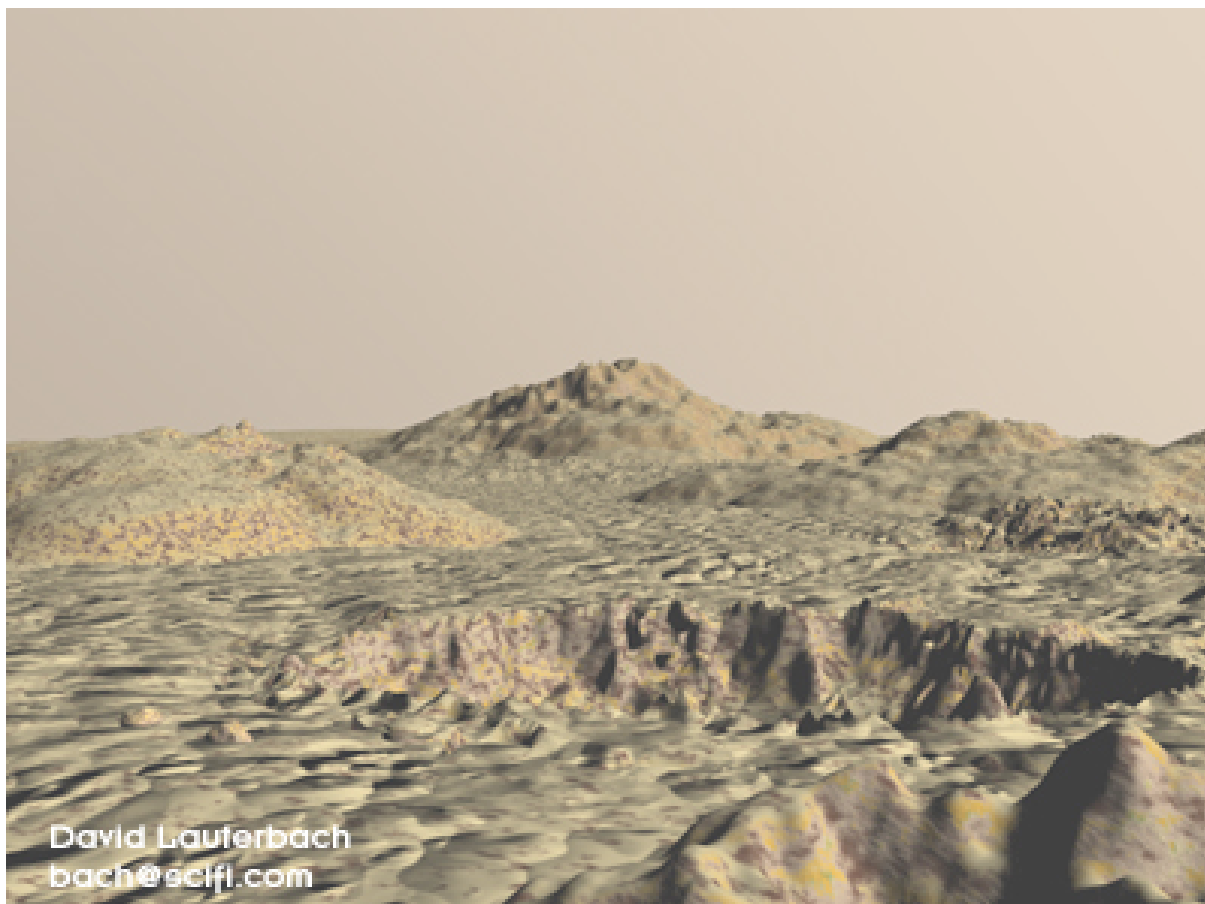


Energy & Time Requirements for Terraforming Mars

Initial State	Final State	Amount	Energy [J m <sup>-2</sup> ]	Solar Energy <sup>a</sup> [years]	Time [years]
Surface Warming					
CO <sub>2</sub> (s) at -125°C	CO <sub>2</sub> (g) at 15°C	200 kPa; 5.4x10 <sup>4</sup> kg m <sup>-2</sup>	3.7x10 <sup>10</sup>	7.9	
Dirt at -60°C	Dirt at 15°C	~10 m; 2x10 <sup>4</sup> kg m <sup>-2</sup>	1.2x10 <sup>9</sup>	0.3	
H <sub>2</sub> O(s) at -60°C	H <sub>2</sub> O(l) at 15°C	10 m; 1x10 <sup>4</sup> kg m <sup>-2</sup>	5.5x10 <sup>9</sup>	1.2	
H <sub>2</sub> O(s) at -60°C	H <sub>2</sub> O(g) at 15°C	2 kPa; 5.4x10 <sup>3</sup> kg m <sup>-2</sup>	1.6x10 <sup>9</sup>	0.33	
Total:				10	100 ✓
Deep Warming					
H <sub>2</sub> O(s) at -60°C	H <sub>2</sub> O(l) at 15°C	500 m; 5x10 <sup>5</sup> kg m <sup>-2</sup>	2.8x10 <sup>11</sup>	56	500
Making O <sub>2</sub>					
CO <sub>2</sub> (g) + H <sub>2</sub> O	CH <sub>2</sub> O + O <sub>2</sub> (g)	20 kPa; 5.4x10 <sup>3</sup> kg m <sup>-2</sup>	8x10 <sup>10</sup>	17	100000 ✗

<sup>a</sup> Energy divided by the total solar energy reaching Mars in a year, 4.68x10<sup>9</sup> J m<sup>-2</sup> yr<sup>-1</sup>

Adapted from McKay *et al.*, 1991. *Nature* **352**, 489-496.



David Lauferbach  
bach@scifi.com

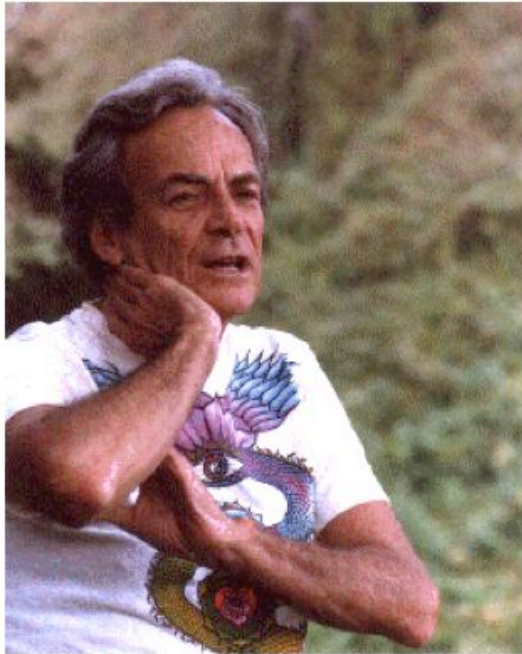


## The Astrobiology Questions

(from the first CAN for Astrobiology from NASA HQ 1997)

1. How do habitable worlds form and how do they evolve?
2. How did living systems emerge?
3. How can other biospheres be recognized?
4. How have the Earth and its biosphere influenced each other over time?
5. How do rapid changes in the environment affect emergent ecosystem properties and their evolution?
6. What is the potential for survival and biological evolution beyond the planet of origin? **\*NEW\***

*What I cannot create I do not understand.*



**Richard P. Feynman**  
written on his office blackboard  
as he left it for the last time  
in January 1988









## Claudia L'Amoreaux

Linden Lab

Claudia L'Amoreaux is a Community Manager at Linden Lab, creators of the trailblazing virtual world, Second Life. Claudia supports middle school and secondary school educators using Second Life to facilitate extremely immersive, constructivist learning experiences with their students.

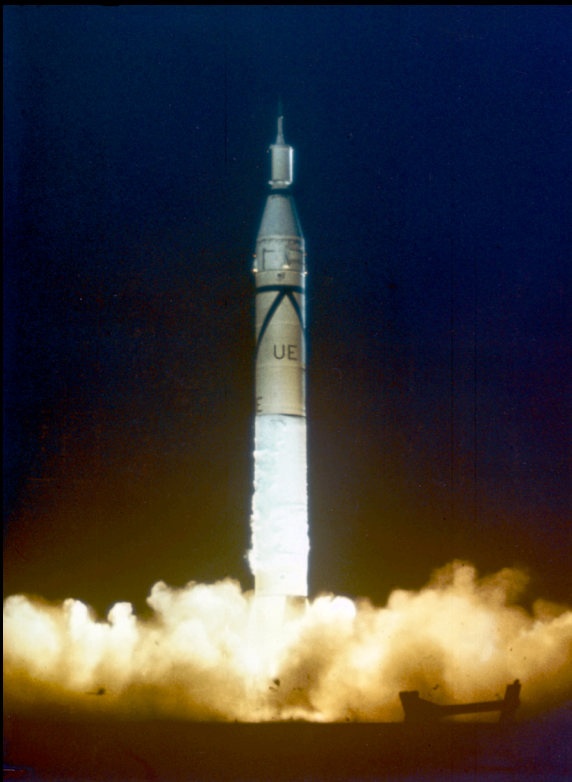
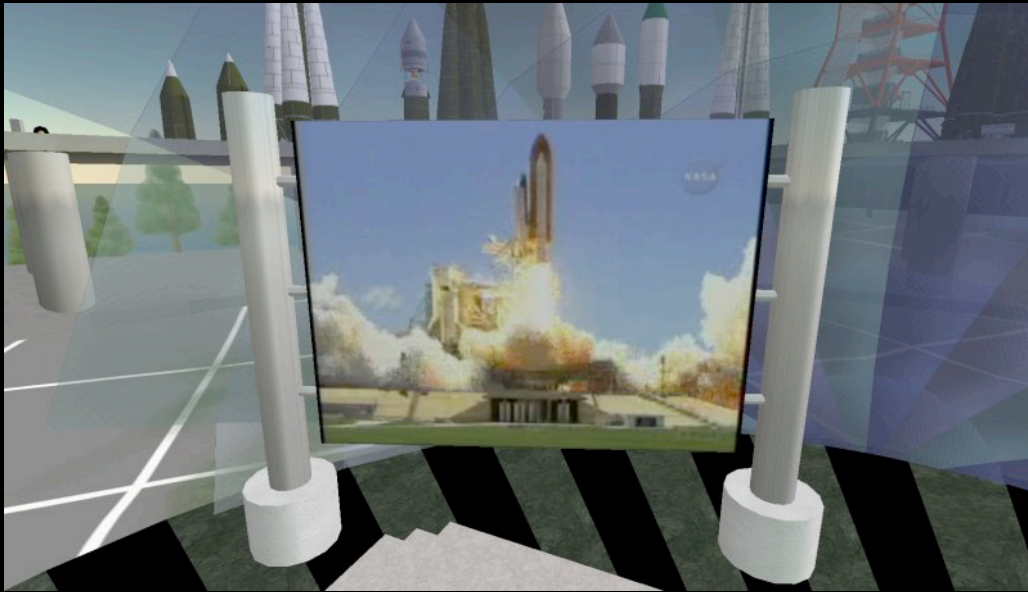


Before joining Linden Lab, Claudia ran her own eLearning consulting company, pioneering collaborative learning on the Internet since 1985. An early adopter, she started using one of the first networked 3D virtual worlds--Worlds Chat--in 1995. She has provided leadership on internet education projects in the U.S., Brazil, Fiji, Europe, and the Middle East. She is co-founder of the Meta-Learning Lab. Her work has been featured on New Dimensions World Broadcasting Network, BBC World Radio in their Essential Guide to the New Millennium, and in the film, *On the Wild Side--Meetings with Remarkable Women*. She co-authored the book */Creating Learning Communities/*. Claudia received her BA from Raymond College at the University of the Pacific--her focus was on alternative futures. She turned 17 a few days after Neil Armstrong walked on the moon. In Second Life, she wears a C-Tech jet pack and lives in a sky pod.



# Virtual Worlds, Virtual Exploration

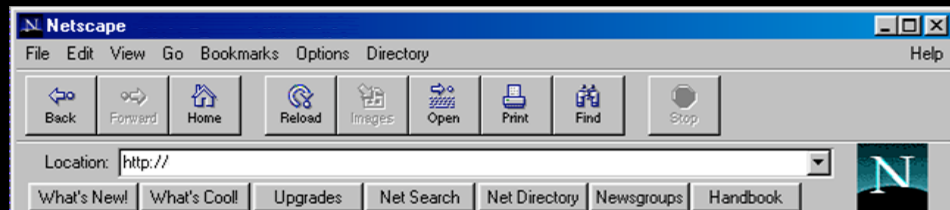
Claudia L'Amoreaux, Linden Lab



## The First Explorer

...was launched into Earth orbit on February 1, 1958. It carried instruments to measure temperatures, micrometeorite impacts, and an experiment designed by James A. Van Allen to measure the density of electrons and ions in space. The measurements made by Van Allen's experiment led to an unexpected and startling discovery -- an earth-encircling belt of high energy electrons and ions trapped in the magnetosphere now known as the Van Allen Radiation Belt.

1994 >



2006 >

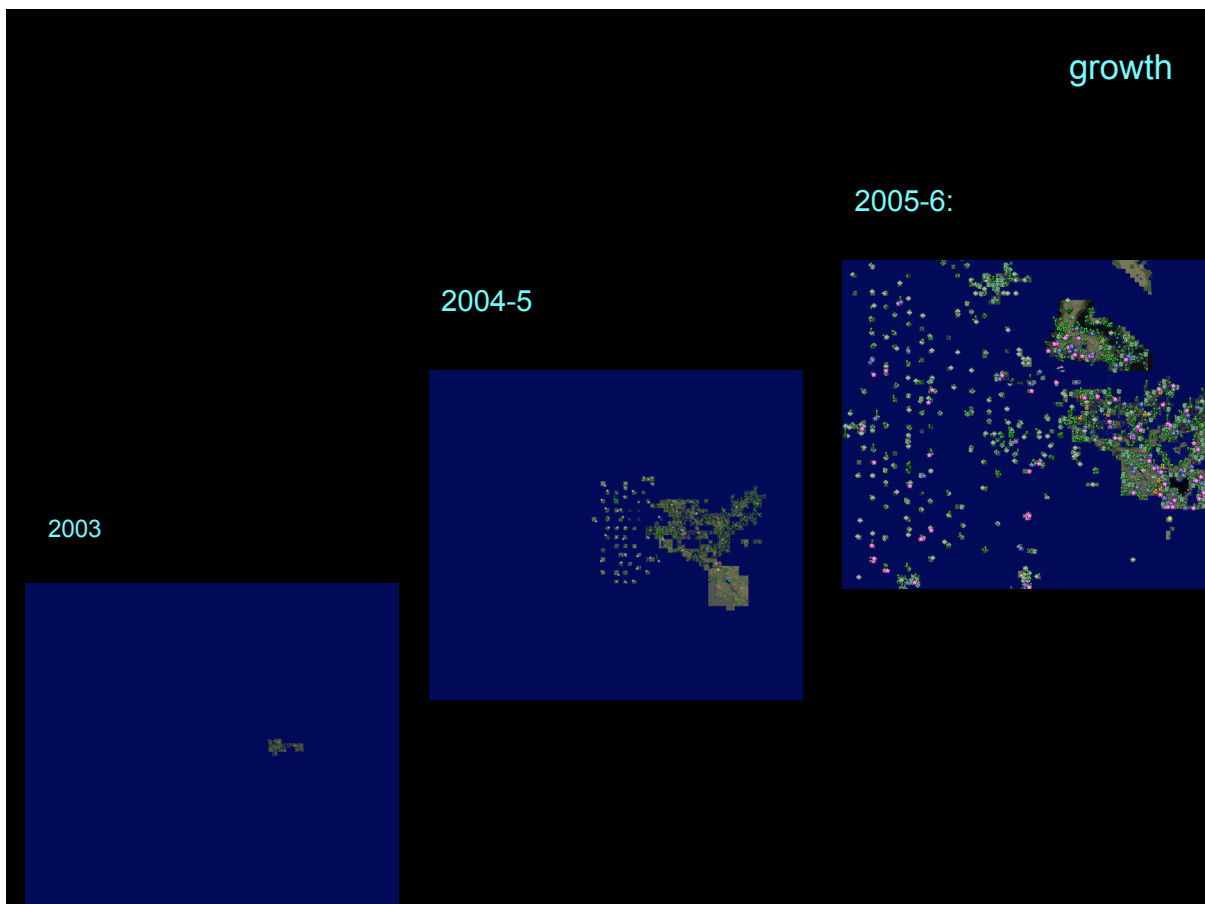








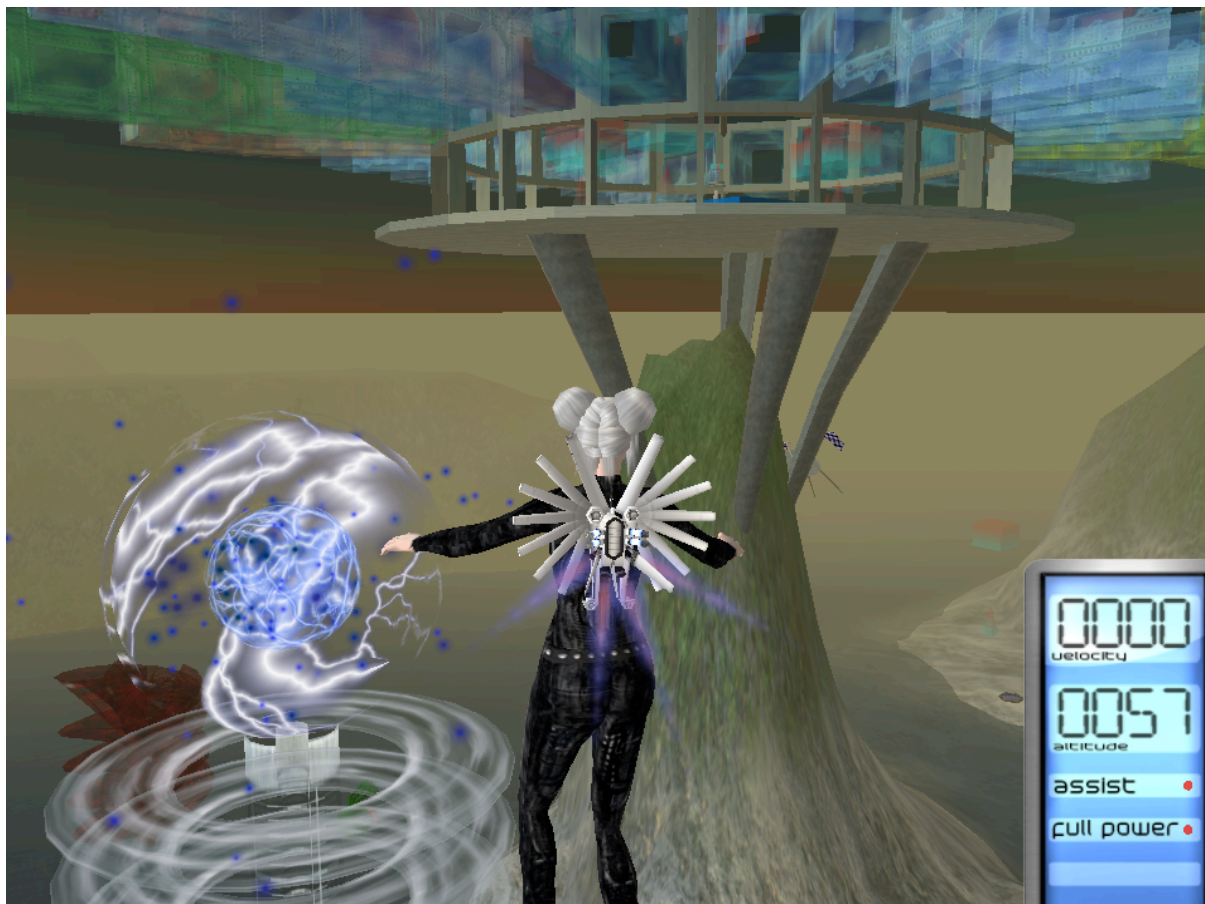




















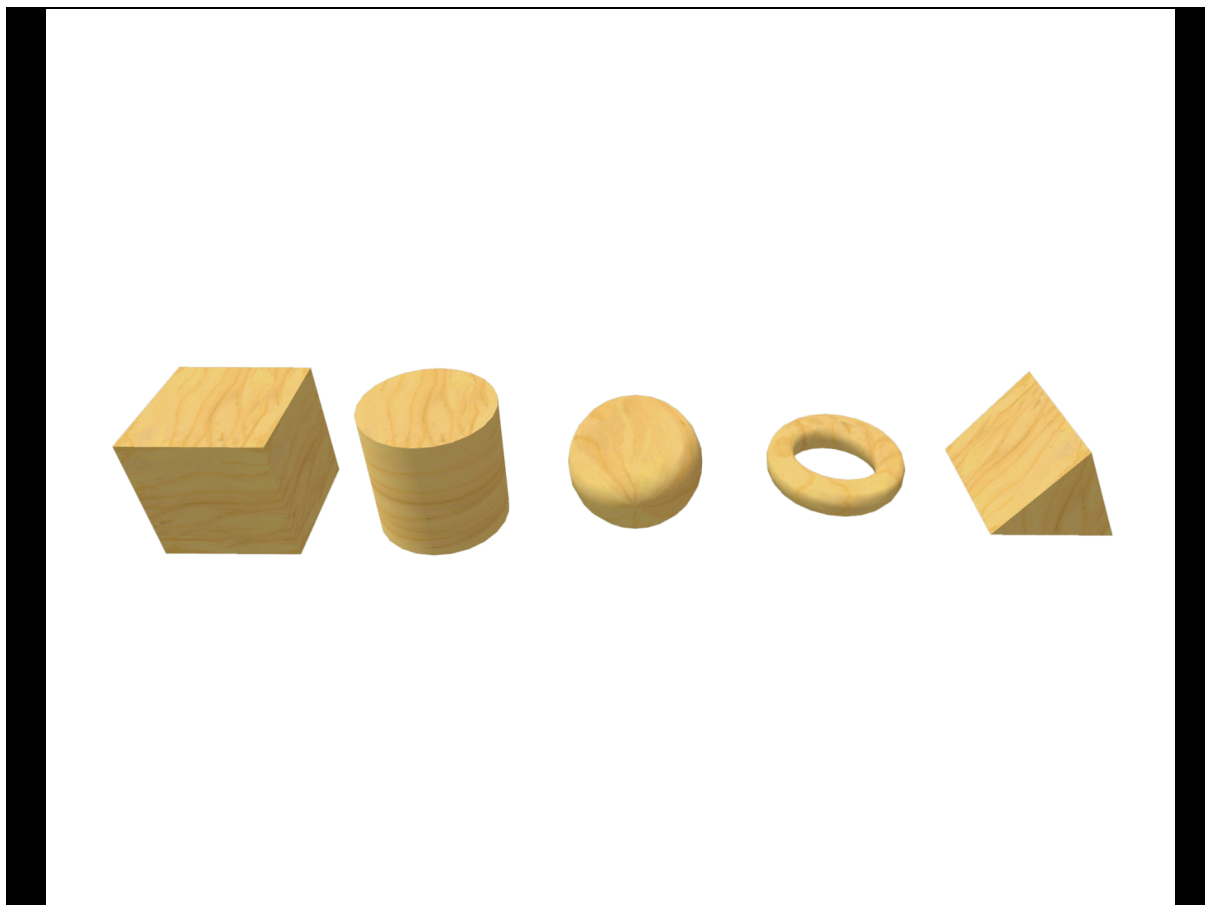
## Emotional Bandwidth

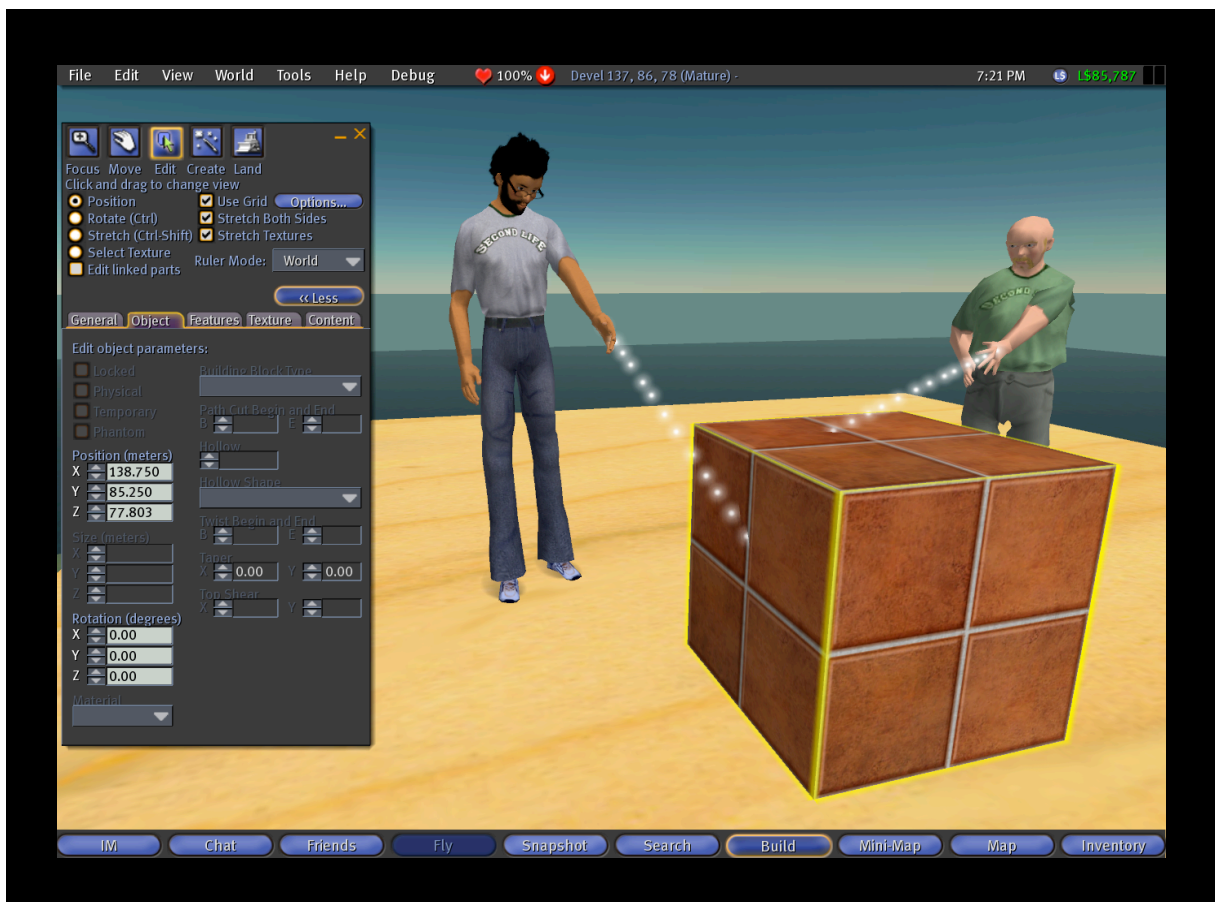
:( :) ;P

## Enriched Presence

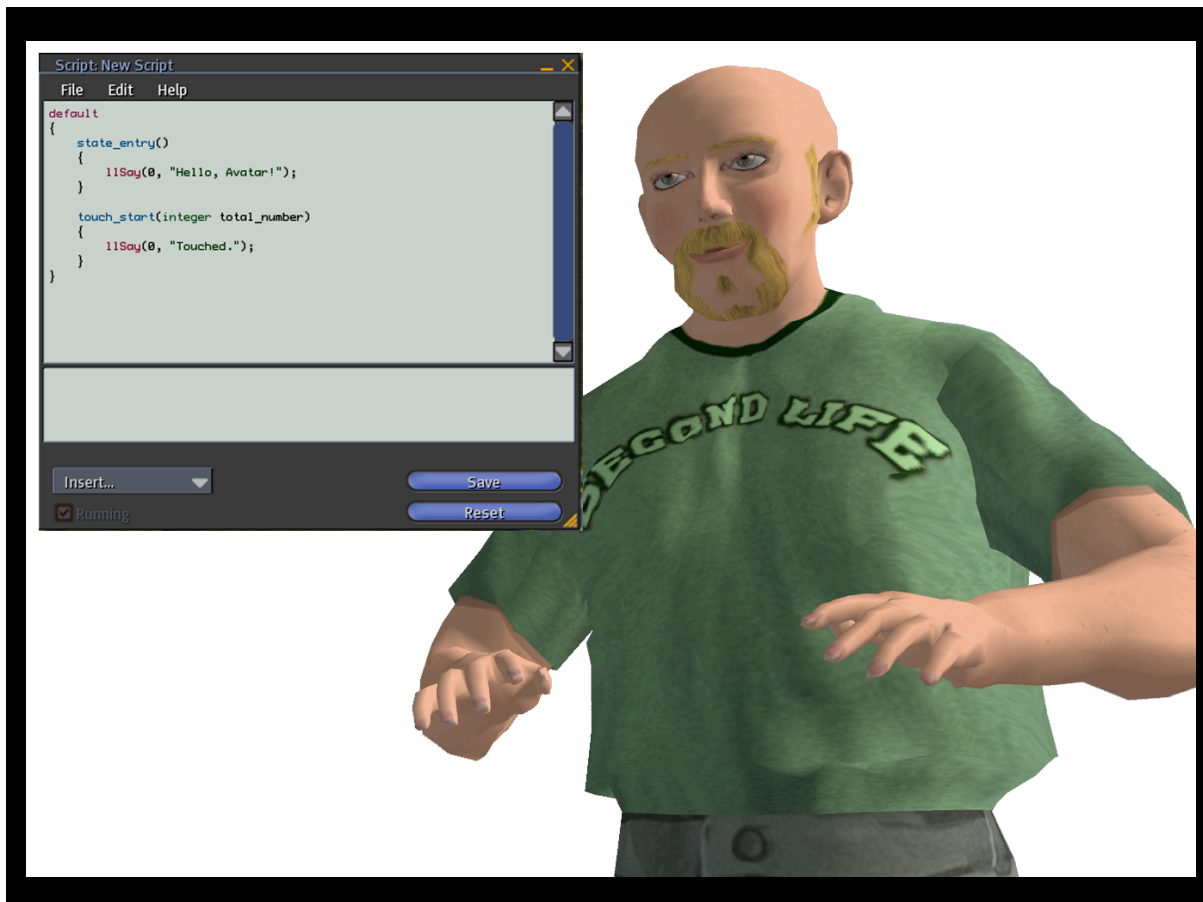




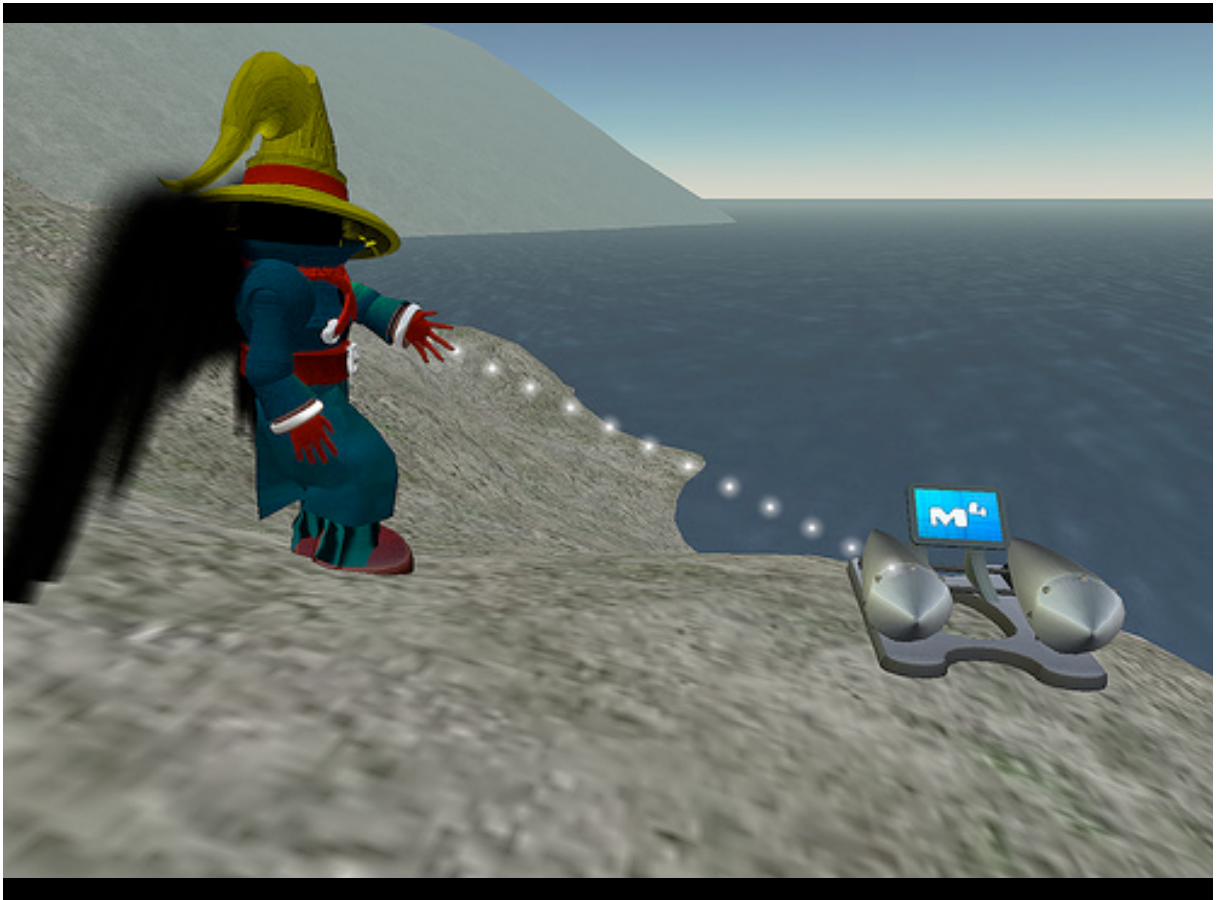




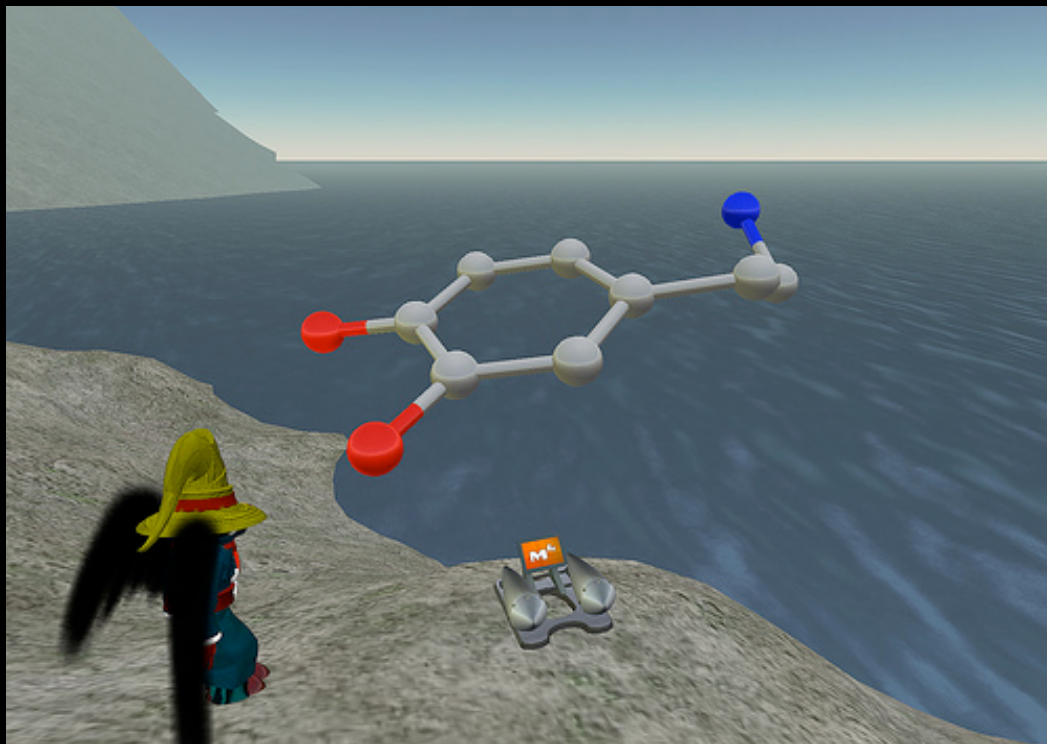




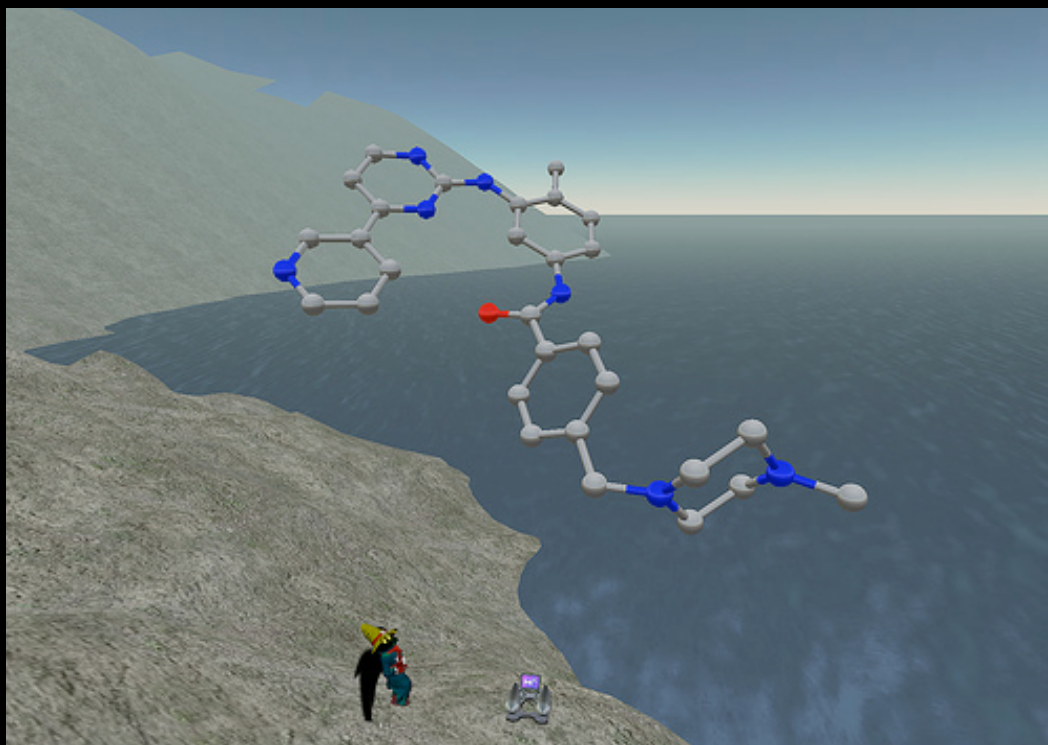




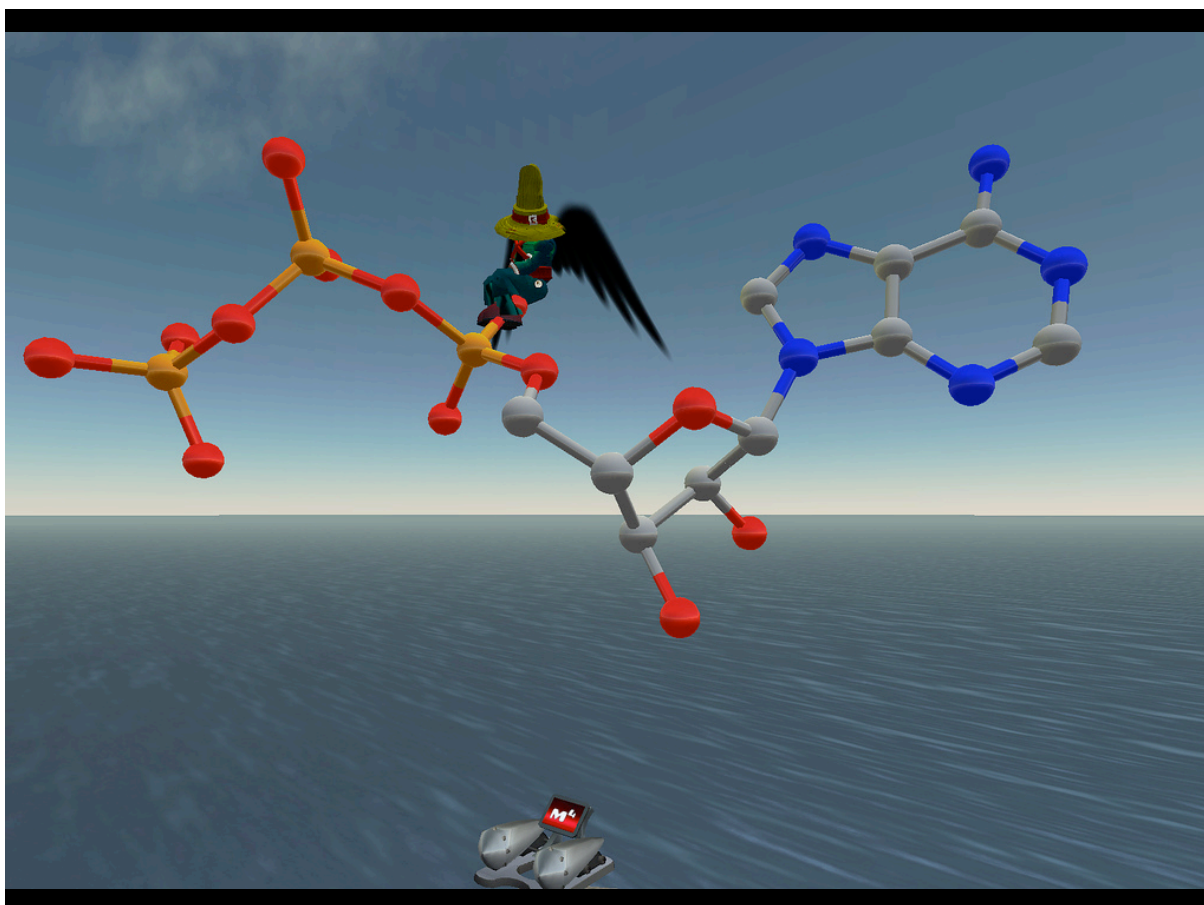
dopamine



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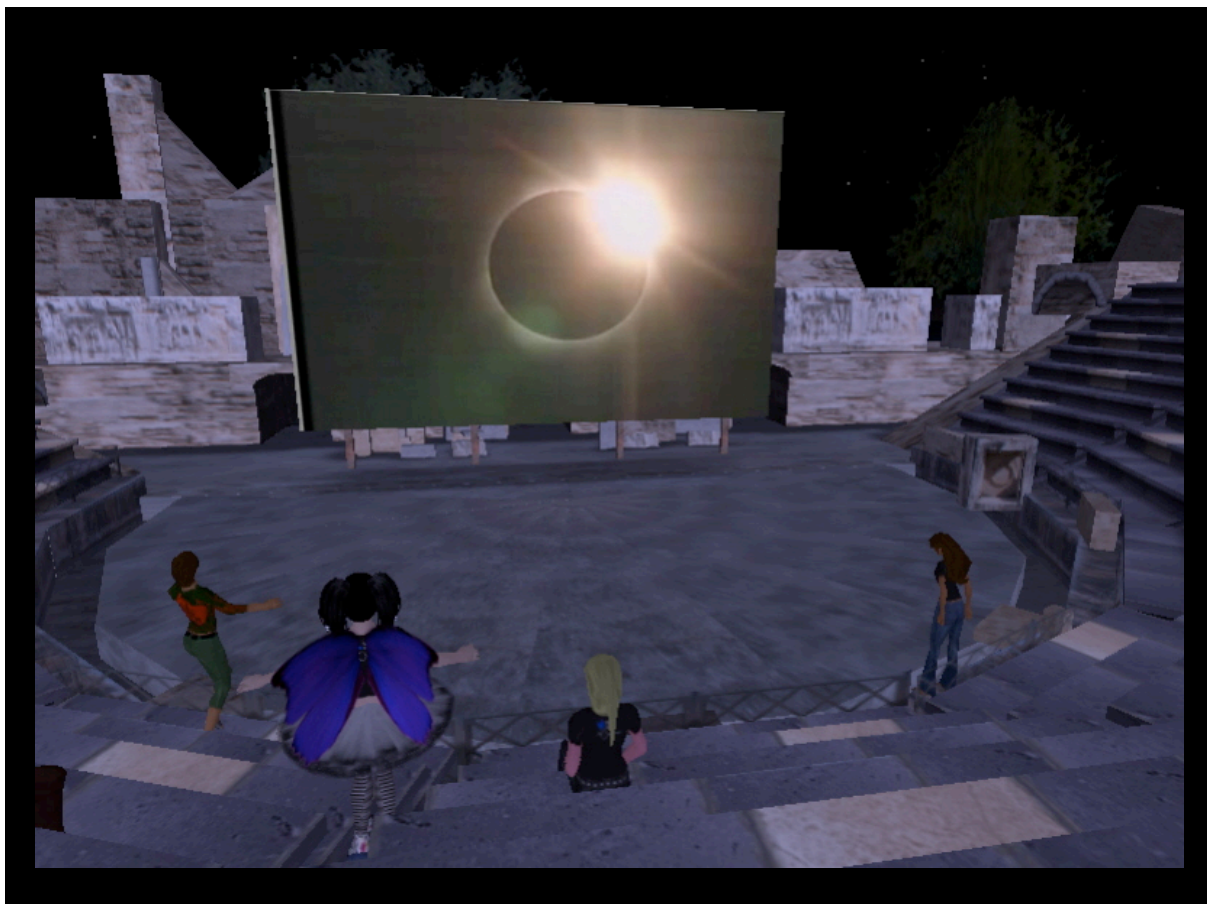




## Solar Eclipse - March 29, 2006 Exploratorium in Second Life

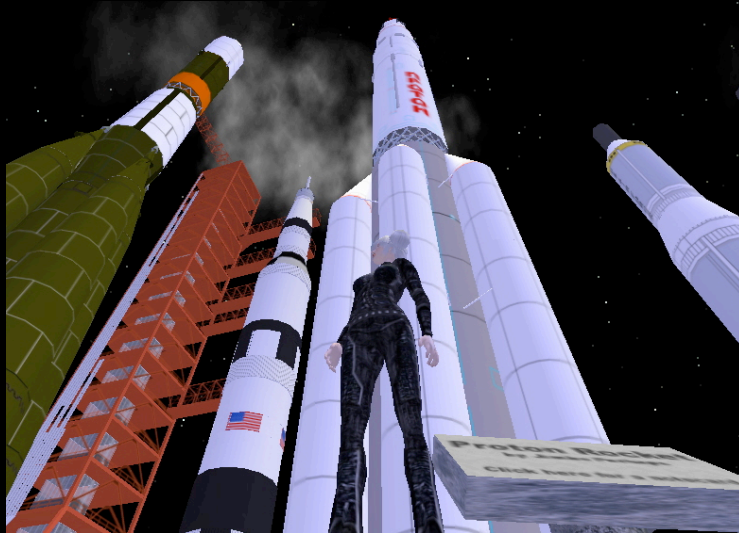






# The International Spaceflight Museum

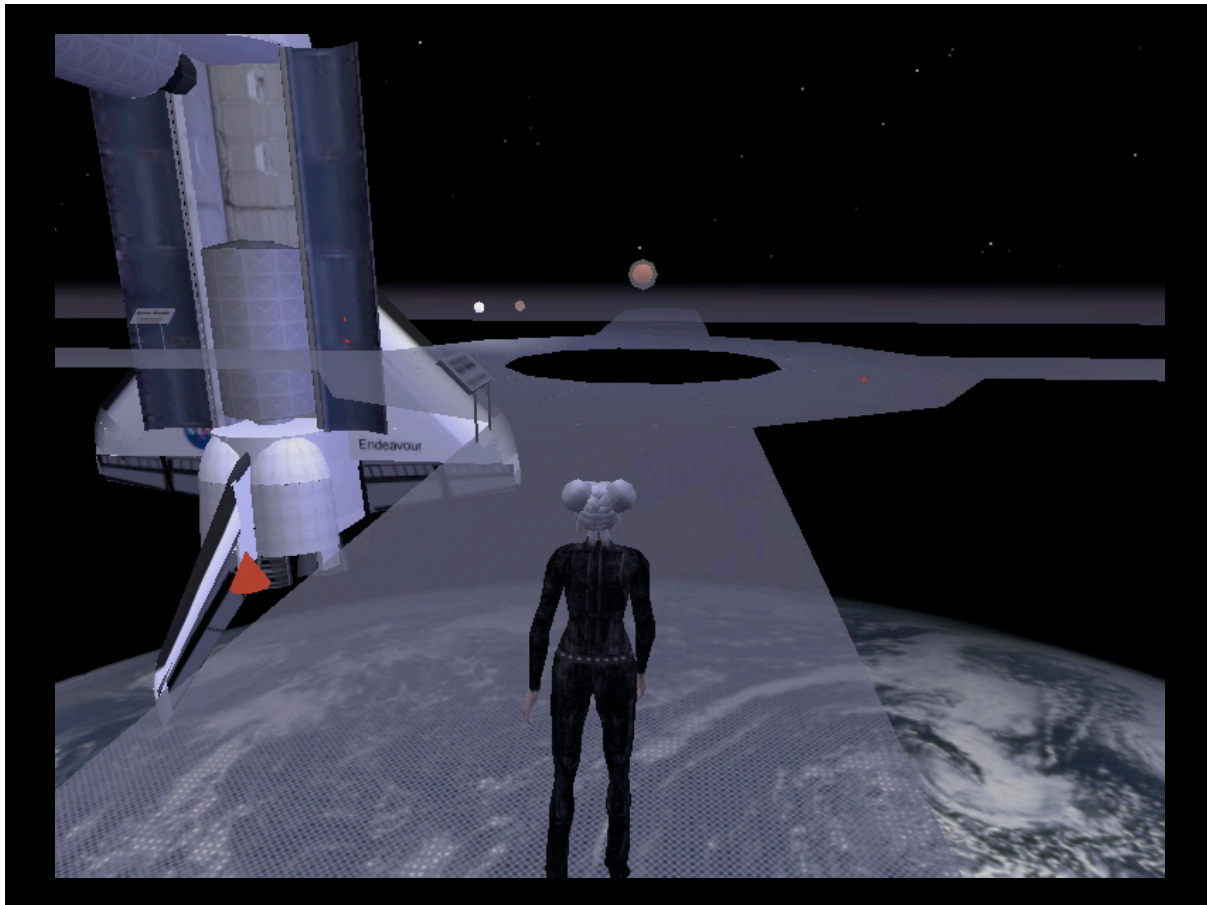
## Spaceport Alpha



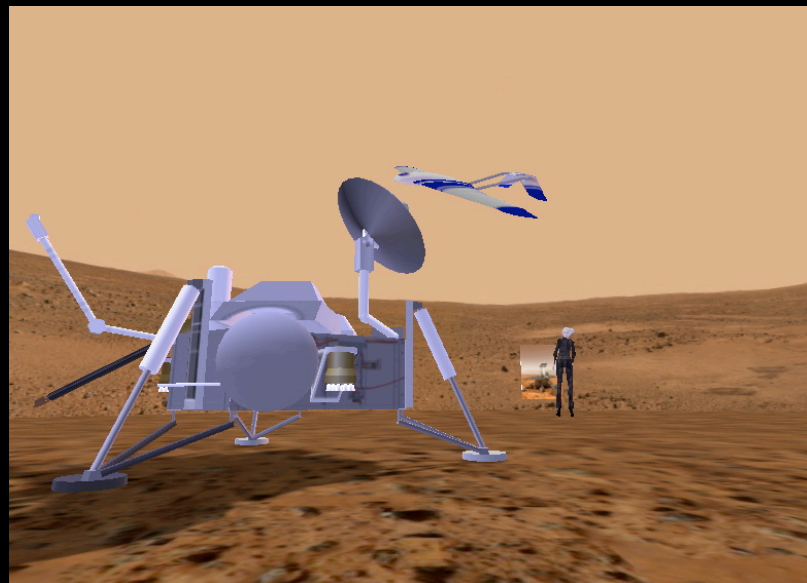
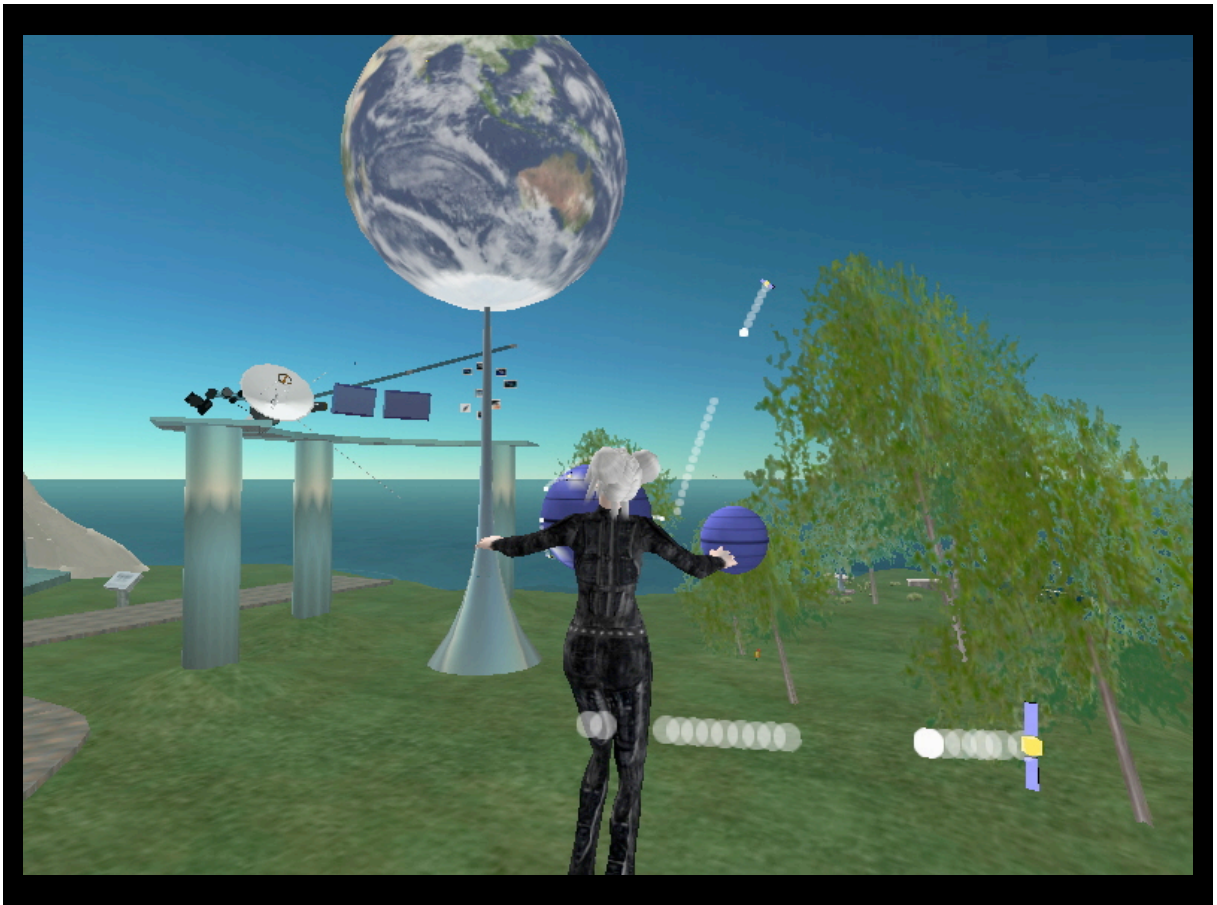
<http://slispaceflightmuseum.org/drupal/>











# NOAA/ESRL Tsunami Simulation

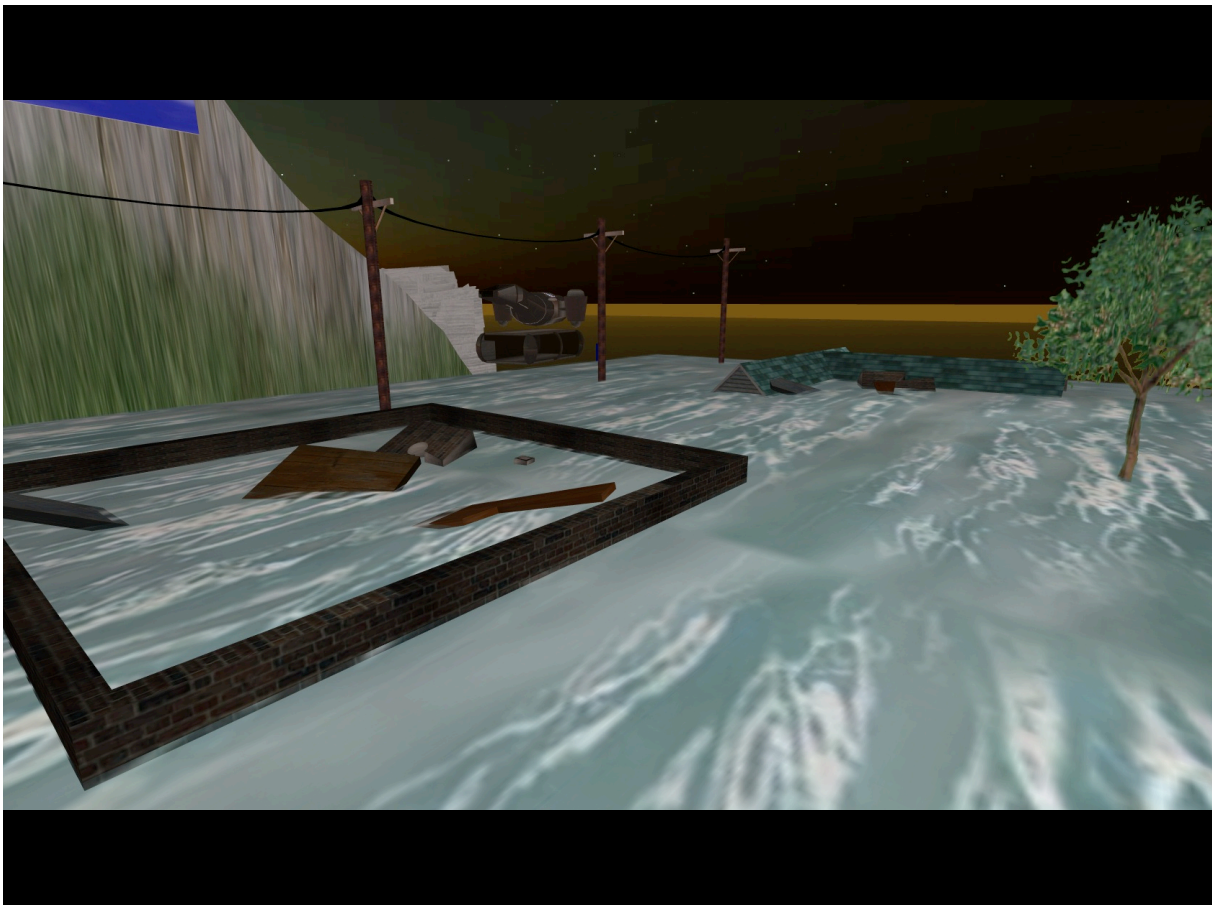
National Oceanic & Atmospheric Administration/  
Earth Systems Research Laboratory













## Inner Space – the space of simulation





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unexpected and startling  
discoveries...



[www.secondlife.com](http://www.secondlife.com)




# **Working Group Reports & Presentations** from the **Next Generation Exploration Conference**



# Asteroids

























## Working Group Report

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Marshal Blessing 

**Co-Moderators:**  
Elisa Quintana   
Rocky Persaud 

**Rapporteur:**  
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Rob Landis			Philip Venturelli



## Asteroids Working Group

Part of the Next Generation Exploration Conference

### Declaration

*The economic potential of thousands of near-earth asteroids (NEAs) will help to support future exploration endeavors and human presence in space. Strong evidence suggests that NEAs are rich in metals, water, and/or organic materials, and reaching them will require relatively low fuel costs. Extracted materials from the NEAs can be used to manufacture structures, fuel, and other resources for mankind's exploration of the solar system. In addition, NEAs have a large range of orbits, allowing some to be utilized as traveling resource platforms that may also be used for low-energy transportation and scientific study of our solar system. Finally, as history has proven, NEAs can collide with Earth and have potentially catastrophic consequences to life and infrastructure. Exploration and understanding of asteroids is essential to humanity's future, both on Earth and in space.*

### 1.0 Introduction

#### 2.0 Themes

- 2.1 Utilize the unique attributes of Near-Earth Objects (NEOs) to enable and enhance sustainable robotic and human space exploration into the solar system
- 2.2 Pursue scientific activities to address fundamental questions about Asteroids, the solar system, the universe, and our place in them
- 2.3 To characterize and mitigate the risk Asteroids pose to life and infrastructure
- 2.4 Supported Themes for Categories

#### 3.0 Objectives

- 3.1 Astronomy and Astrophysics
- 3.2 Heliophysics
- 3.3 Geology
- 3.4 Life Support and Habitat
- 3.5 Environmental Hazard Mitigation
- 3.6 Materials Processing
- 3.7 Communication and Navigation
- 3.8 Power
- 3.9 Surface Mobility
- 3.10 Operational Environmental Monitoring
- 3.11 Crew Activity
- 3.12 Asteroid Resource Utilization
- 3.13 Commercial Opportunity
- 3.14 Public Engagement and Inspiration
- 3.15 Transportation
- 3.16 Global Partnership
- 3.17 Program Execution
- 3.18 General Infrastructure
- 3.19 Operations Test and Verification
- 3.20 Guidance, Navigation and Control

#### 4.0 Issues and Enablers



### 5.0 Action Items:

- 5.1 Asteroid Science and Technology Recommendations / Notional Asteroid Missions
- 5.2 Education and Public Outreach

## 1.0 Introduction

The study and utilization of asteroids will be an economical way to enable exploration of the solar system and extend human presence in space. There are thousands of near-earth objects (NEOs) that we will be able to reach. They offer resources, transportation, and exploration platforms, but also present a potential threat to civilization.

Asteroids play a catastrophic role in the history of the Earth. Geological records indicate a regular history of massive impacts, which astronomical observations confirm is likely to continue with potentially devastating consequences. However, study and exploration of near earth asteroids can significantly increase advanced warning of an Earth impact, and potentially lead to the technology necessary to avert such a collision. Efforts to detect and prevent cataclysmic events would tend to foster and likely require international cooperation toward a unified goal of self-preservation. Exploration of asteroids will help us to understand our history and perhaps save our future.

Besides the obvious and compelling scientific and security drivers for asteroid research and exploration, there are numerous engineering and industrial applications for near-term asteroid exploration.

We have strong evidence that some asteroids are metal rich. Some are water and organic rich. They can be reached with a very low fuel cost compared to other solar system destinations. Once we reach them, there are efficient, simple extraction technologies available that would facilitate utilization. In addition, the costs of returning extracted resources from asteroids will be a fraction of the cost to return similar resources from the moon to Low Earth Orbit (LEO). These raw materials, extracted and shipped at relatively low cost, can be used to manufacture structures, fuel, and products which could be used to foster mankind's further exploration of the solar system.

Asteroids also have the potential to offer transport to several destinations in the solar system. In addition to Mars and the Asteroid belt, it is possible to nudge the orbits of NEOs to provide convenient transport to other destinations. Resources to support life on these long voyages may be gathered from the host asteroid itself. As asteroids travel over a wide range of inclinations and ranges, they offer possible platforms to perform scientific investigations. These include unique vantage point observations of the sun and planets. These observations can help us to understand solar activity and space weather. They also afford us an opportunity to see how the earth looks from afar with different perspectives. When we look for planets outside of our solar system, these observations will help us to calibrate our data. Asteroids may also be used as platforms to support very long baseline interferometry with unprecedented angular resolutions.

## 2.0 Themes

*2.1 Utilize the unique attributes of Near-Earth Objects (NEOs) to enable and enhance sustainable robotic and human space exploration into the solar system.*

Develop the technologies and operations necessary to make effective use of the resources NEOs provide, including:

- Extraction of abundant natural resources and raw materials necessary for exploration (water, regolith, metals)
- Use of NEOs as a low-energy “transit” system between the orbits of Earth, Mars, and the asteroid belt.

*2.2 Pursue scientific activities to address fundamental questions about Asteroids, the solar system, the universe, and our place in them*

Engage in scientific investigations:

- Of the Asteroids: Study the history of the Asteroids, their composition, and structure to learn about the evolution of our solar system;
- From the Asteroids: Use Asteroids as a traveling platform for performing scientific investigations.

*2.3 To characterize and mitigate the risk Asteroids pose to life and infrastructure.*

Study and catalog Asteroids and develop procedures to avert undesirable asteroid collisions with Earth, spacecraft, habitations beyond Earth, and infrastructure throughout the solar system.

*2.4 Supported Themes for Categories*

For the purposes of comparing and contrasting Asteroid objectives (below), we have defined six supporting themes:

- Science
- Exploration
- Impact Prevention
- Commerce / Earth Benefit
- Global Partnership
- Public Engagement

## 3.0 Objectives

### *3.1 Astronomy and Astrophysics*

#### *3.1.1 Observe Earth and other planets as a Calibrator for extra solar planets detection*

Summary: The search for extra-solar planets will yield photometric and spectroscopic light curves. To determine if these extra solar planets have life or could support life, we need a calibrator such as the earth.

Value: Asteroids can carry instruments to locations offering different vantage points of the earth and other planets. These instruments can be revisited when the asteroid returns closer to earth.

#### *3.1.2 Use as a platform for VLBI Astrophysics*

Summary: The highest angular resolution for astrophysics is afforded by interferometry.

Value: Asteroids can provide rides for radio telescopes that can work in conjunction with those on other asteroids as well as on the earth and moon to provide very long baselines and unrivaled angular resolution making possible great advances in astrophysics and cosmology.

#### *3.1.3 Study Zodiacal Dust*

Summary: Study the zodiacal dust to determine its effect on extra solar planet detection.

Dust within our solar system may affect these measurements. Also, dust in extrasolar systems can affect the detection of earth like planets.

Value: Asteroids can be chosen that sample various regions of the solar system and provide distribution information. For example, samples taken from above or below the ecliptic plane can potentially yield valuable information.

### *3.2 Heliophysics*

#### *3.2.1 Observe the Sun*

Summary: Learn about global solar phenomena with multiwavelength observations.

Understand space weather.

Value: Asteroids can offer different perspectives (including solar poles and far side of the sun) on the sun than those measurements just from the earth. In particular, we can choose asteroids that can give us far-side views of the sun simultaneous to earth observations and therefore get a more global view of solar phenomena.

#### *3.2.2 Observe and Characterize the Solar Wind*

Summary: Learn about the solar wind and space weather.

Value: Asteroids can offer different perspectives on the sun than those measurements just from the earth. In particular, we can choose asteroids that can give us farside views of the sun simultaneous to earth observations and therefore get a more global view of solar phenomena.

### *3.3 Geology*

#### *3.3.1 Understand the origin, composition, and structure of Asteroids*

Summary: Determine the internal structure, mineral composition, and dynamics of Asteroids using a long-lived and extensive network of seismometers and/or penetrators and/or in situ and sample return analysis.

Value: The study of asteroids will help establish connections with existing meteorite collections. Asteroids may provide information about the state of the solar system from



formation to the present time. Knowledge of the composition is important for resource exploitation.

*3.3.2 Gain a better understanding of the history of the moon by studying impact craters on asteroids*

Summary: Make crater size and number distribution measurements. Correlate these with independent measurements of age.

Value: This will give collision rates that can be applied to lunar history models.

*3.3.3 Study water and other volatiles on asteroids*

Summary: Identify and quantify water and other volatiles and measure the distribution within the asteroid.

Value: Asteroids and comets are believed to be the source of any water and organics to the early earth and that we may find on the moon and other planets. Also, they may be the best source of these useful resources for exploration.

*3.3.4 Characterize potential resources*

Summary: Locate and quantify (develop planetary-scale maps) surface/near-surface deposits of potentially valuable resources, including both minerals and water.

Value: Future exploitation of asteroid resources is facilitated if a global surface map of these resources exists. Such a resource map is also of scientific value in helping to define variations in surface compositions.

*3.3.5 Characterize the impact process*

Summary: Study the physical and compositional effects of hypervelocity impact using lunar craters, from micron-sized zap pits to multi-ring basins. Study excavation and modification stages of impact process and their physical and compositional effects. Study the transport and mixing of materials as a result of impacts. Study the morphology of freshly formed craters and of their ejecta distribution.

Value: Use record of impacts preserved on the Asteroids to unravel complex processes, operative on all the planets. Will help characterize the recent impact rate and gardening rate.

*3.4 Life Support and Habitat*

*3.4.1 Provide safe and enduring habitation systems to protect individuals, equipment, and associated infrastructure*

Summary: During short and long-duration stays on an asteroid, individuals will need a habitat that will protect them from the environment. A number of implementation strategies are possible for this habitat, including using regolith as protection from radiation, and meteorite impact. In addition protection must be afforded to individuals and equipment traveling to/from the asteroid. Inside the habitats, basic life support and recreational activities should be provided to the crew. Over time, the life support systems should move from open to closed systems, with food production, water and air regeneration, and waste management systems.

*3.4.2 Improve upon existing biologically based life support system components to support long duration human exploration missions*

Summary: A number of plant and bacterial species have been identified for studying

fundamental and applied topics related to the long term effects of the environment on processes associated with bioregenerative life support systems. These studies will determine the feasibility of integrating plants and microbes into the life-support systems for food production and treatment of water, air, and solid wastes.

### *3.4.3 Provide agriculture services to support life support systems*

Summary: Agricultural services include the use of regolith as the growing medium for plants and crops, or the operation of a green-house or farm using imported (e.g. Earth soil or hydroponic) medium.

### *3.4.4 Provide health care services to aid life support operations*

Summary: "In-Situ" medical care will be an important facet of working and living. Common ailments (e.g., colds, flu) can be treated medically without major impact to the mission execution. More serious problems (e.g., muscle strains, broken bones) may require stabilization of the patient and immediate (or near-immediate) return to Earth.

## *3.5 Materials Processing*

### *3.5.1 Beneficiation*

Summary: The process of enriching or separating minerals.

### *3.5.2 Regolith Digging*

Summary: Designing the processes and developing the equipment necessary to dig regolith.

### *3.5.3 Environment Sealing*

Summary: Sealing processing chambers in the presence of Asteroid regolith and dust.

### *3.5.4 Processing Techniques*

Summary: Utilizing the environment and minimizing the equipment necessary for chemically and mechanically processing material/minerals into useful products.

### *3.5.5 Mineral Sieving*

Summary: Separating differences in size and shape of minerals and materials.

### *3.5.6 Material Collection*

Summary: Designing the processes and developing the equipment necessary to collect minerals, ores, and materials.

### *3.5.7 Material Storage*

Summary: Refrigeration and Liquefaction of processed materials and minerals.

## *3.6 Communication and Navigation*

### *3.6.1 Interplanetary Internet*

Summary: Ubiquitous communication and navigation that is secure, reliable with high-bandwidth.

### *3.6.2 Autonomous systems and expert systems*

Summary: Allowing reduced communications requirements

### 3.7 Power

#### 3.7.1 Solar Energy

Summary: Utilize direct solar power as primary energy source for processing needs.

#### 3.7.2 Requirement Definition and Characterization

Summary: Identify and define power and energy requirements for Asteroid activities (science, resource utilization, habitation, and threat mitigation).

### 3.8 Surface Mobility

3.8.1 *Implement surface mobility systems to support both crew and cargo traverses in reduced gravity*

3.8.2 *Provide surface mobility capabilities for the purpose of constructing and operating an outpost*

### 3.9 Operational Environmental Monitoring

3.9.1 *Monitor space weather to protect inhabitants and gather data about our solar system*

3.9.2 *Monitor real-time environmental variables affecting safe operations*

### 3.10 Crew Activity

3.10.1 *Develop teleoperation capabilities to support human operation of equipment on the asteroid's surface. Implement human interaction systems (telepresence) to support automation technologies required for lunar operations.*

3.10.2 *Provide arts, entertainment, recreation, and leisure activities because for the well-being of the crew*

### 3.11 Asteroid Resource Utilization

#### 3.11.1 Characterization

Summary: Determine minerals present and the chemical and physical distribution of these minerals. Characterize the surface and subsurface mechanical properties of Asteroids.

#### 3.11.2 Sample Return

Summary: Collect representative samples and return them to a laboratory.

#### 3.11.3 Fabrication

Summary: Building of structural elements on the surface of Asteroids.

#### 3.11.4 Resource- and Environment- Appropriate Refining Technologies

Summary: Turning beneficiated minerals into useful raw materials.

### 3.12 Commercial Opportunity

#### 3.12.1 Business Plan

Summary: Establish viable business models and productive companies performing asteroid resource extraction and processing.



### 3.12.2 *Tourism*

Summary: Development of an Asteroid tourism industry.

### 3.12.3 *Insurance*

Summary: Establish a reasonable insurance environment that encourages Asteroid commerce.

### 3.12.4 *Legal*

Summary: Establish a reasonable legal regime encouraging Asteroid commerce and investment, including property rights protection.

### 3.12.5 *Environmental Issues*

Summary: Establish favorable environmental assessment and protection requirements.

### 3.12.6 *Energy*

Summary: Develop technologies for fabricating solar generation facilities from asteroid products

## 3.13 *Public Engagement and Inspiration*

3.13.1 *Extend awareness of space activities to diverse, non-traditional communities, utilizing non-traditional means, to enhance public engagement.*

Summary: Non-traditional methods of public engagement are rarely used for the space program. The proposal would to involve musicians, artists, poets, story tellers, etc. in public outreach about space to try and reach the general public in a new way. Non-traditional methods have proved effective in formal and informal education settings as well.

Value: The value of these diverse methods is that they may reach a set of the population not touched by traditional education and public outreach activities. These education activities could expand the workforce by demonstrating the excitement of and reasons for space exploration to diverse communities

## 3.14 *Transportation*

3.14.1 *Provide redundant transportation services to and from the asteroid*

3.14.2 *Develop reliable methods of transporting materials to and from an asteroid*

3.14.3 *Develop methods of using an asteroid as a spacecraft to more distant exploration objectives*

3.14.4 *Optimize transportation methods to minimize thrust and delta v requirements*

## 3.15 *Global Partnership*

3.15.1 *Establish a global partnership framework to enable all interested parties (including non-space faring nations and private companies) to participate in asteroid exploration and resource utilization.*

Summary: A global framework, able to encompass both commercial and governmental involvement, should be established to coordinate the asteroid-related activities of all interested parties. This framework should allow for (but may not require) coordination of road-maps and missions, sharing of infrastructure and facilities, while maintaining autonomy (if desired) of participants.

Value: International collaboration, including government-government, government-commercial, and commercial-commercial, (where government involvement can be at the state or province level) can be efficient, cost effective, enable the long-term stability of the program, and promote international peace. Fostering collaboration has the potential to increase the amount of asteroid activity by increasing the total amount of financial and human resources available to the endeavor and increasing the level of public support. Finally, by allowing participants to maintain their autonomy within the overall program, each participant can establish their own goals, as best suit the needs of their stakeholders.

*3.15.2 Establish standards and common interface designs to enable interoperability of systems developed by a global community.*

Summary: Use existing standards and establish new standards for data, communication, and equipment. Standards should enable systems produced by different parties to be interoperable.

Value: Standard interfaces will enable exploration stakeholders to share infrastructure and consumables, thereby enhancing the affordability, sustainability, and safety of asteroid-based activities. Standardization will also allow suppliers to compete across emerging space commerce markets. One of the potential impacts to establishing standards is that it increases the barriers to entry for some participants.

### *3.16 General Infrastructure*

*3.16.1 Provide finance and insurance services to support businesses operating on NEOs.*

Summary: Earth-based banking industry especially for the financing of NEO-related industries.

Value: Financing of NEO-related industries will be an important fundamental step toward self-sufficient and sustainable lunar commerce.

*3.16.2 Provide warehousing services on NEOs.*

Summary: Warehousing is the storage capability for goods in transit between their points of origin and destination.

Value: Inexpensive storage of goods between their points of origin and destination will be very important to the development of a sustainable and self-sufficient NEO business.

*3.16.3 Develop infrastructure and utilities systems on NEOs to aid NEO operations.*

Summary: Utilities can include power generation. Infrastructure can include anchor points or transportation systems. These are capabilities required by virtually all activities that will be conducted on NEO surfaces.

Value: Many basic needs for living and working on NEO surfaces must be met for efficient use of the in-situ resources (including humans working on the surface). Commercially developed infrastructure and utilities would enable government and commercial entities to

### *3.17 Operations Test and Verification*

*3.17.1 Engage in operations testing to understand the effect of the NEO environment on basic working tasks (with timescales applicable to early crewed Moon and Mars missions)*

Summary: Test and refine techniques for living and working in the NEO environment. Individuals living on NEOs should learn how to do everyday things, such as cook, clean, and live their daily lives in a NEO habitat. Techniques must also be refined for basic work

Value: Systematic, comprehensive characterization of how fundamental living and working tasks are best accomplished in the lunar environment. This will speed the acclimatization to living on NEOs.

### *3.18 Guidance, Navigation and Control*

#### *3.18.1 Establish beacons for interplanetary navigation, communication, and threat assessment*

Summary: Put transponders on selections of NEOs ranging between Earth and Mars for use in navigation between planets and NEOs.

Value: Provides interplanetary navigation network. Can provide information on undiscovered NEOs from orbital tracking. Also can be used to understand non-Newtonian dynamics.

#### *3.18.2 Investigate and develop methods for orbit modification*

Summary: It can become necessary to change the orbits of NEOs. As such, developing methods that work are needed.

Value: Provides the capability to change the positions of NEOs for a variety of purposes.

## **4.0 Issues and Enablers:**

1. Interpretations of current international treaties prohibit commercial ownership of resources and should be revised.
2. Establish an international organization with jurisdiction to allocate usage and access rights for asteroids and provide a forum for dispute resolution (modeled after International Telecommunications Union).
3. Establish minimal environmental requirements and abolish biological contamination requirements for asteroids (with appropriate sunset clauses).
4. Develop technological capabilities to operate in the asteroid environments (e.g. In situ operations, materials processing, ubiquitous communications, life support/habitation, autonomous robotic capability, etc).
5. Develop technologies and procedures to detect and deflect asteroids with natural or human altered trajectories that pose a threat.
6. Promote governmental or commercial programs and economic activities that provide an anchor tenant for asteroid derived products.

## **5.0 Action Items:**

### *5.1 Asteroid Science and Technology Recommendations / Notional Asteroid Missions*

Asteroid mission to test strategies for (1) mitigating the risk associated with Earth impact hazard and (2) in situ analysis in preparation for resource utilization. This would include NASA, other space agencies, and non-governmental organizations (NGOs) to ensure that there is a mission to an asteroid in the next decade. We envision a mission that will rendezvous with a carbonaceous asteroid, analyze its composition, extract volatile materials, and



use them to change the orbit of the asteroid.

We recommend that an element for asteroid research for both science and technology be added to future calls for NASA Research Opportunities in Space and Earth Sciences (ROSES). Currently NASA includes asteroid research as a component of Planetary Geology and Geophysics--elevating this to a top level of ROSES will help immediately align the focus of the scientific and engineering community to asteroid research.

We propose a sample return mission from a carbonaceous NEO, which implants a radio transponder for Yarkovsky Effect measurements to better predict asteroid trajectories and assess terrestrial impact hazards. This should be done on as many different spectral classes of NEO to construct taxonomy of these objects. This would get at the heart of understanding the dynamical evolution of these objects as well as gaining a detailed understanding of the chemical composition. This would provide unparalleled information about solar system history and resources in near Earth space.

To demonstrate the transport capability of NEOs, we propose to launch a spacecraft to an NEO, ride it out, and then leave the asteroid on a trajectory to Mars, the asteroid belt or another target. Ideally resources would be extracted from the carbonaceous asteroid during transport and utilized by the spacecraft as propellant.

Finally, we encourage continued and expanded observations of NEO's to assess potential impact threats. This will guide the prioritization of targets for future asteroid missions.

## 5.2 *Education and Public Outreach*

Due to the potentially valuable uses of asteroids for exploration, we recommend the inherent beneficial characteristics of Near-Earth Asteroids which enable early, sustainable exploration of the inner solar system be promoted to various stakeholders (policy-makers, public, engineers, and scientists). Examples of these characteristics include abundant water and mineral resources and low energy orbital transits between NEOs and LEO/HEEO.

To engage universities, we recommend a student designed and built asteroid probe. A competition focused on an asteroid rendezvous, answering meaningful scientific questions and addressing exploration objectives would also engage the current student populations and increase public awareness of the benefits of asteroids.

We recommend that there should be a Centennial Challenge for non-government entities to demonstrate resource extraction from an asteroid.

Finally we recommend space agencies to formalize a sustainable Young Professional's Advisory Body. An advisory body, consisting largely of young professionals, encompassing multiple nationalities and multiple disciplines should be established to provide semi-annual or annual briefs and updates to higher ranking officials that are currently driving the exploration goals. The proposed body should have the support of the main space agencies and current commercial players, and should be empowered to provide recommendations.



# Asteroids Working Group



## Next Generation Exploration CONFERENCE

Emerging global space leaders designing  
the future of space exploration.

**August 16 - 18, 2006**

NASA Ames Research Center • Building 3

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## Introduction



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## Team Members

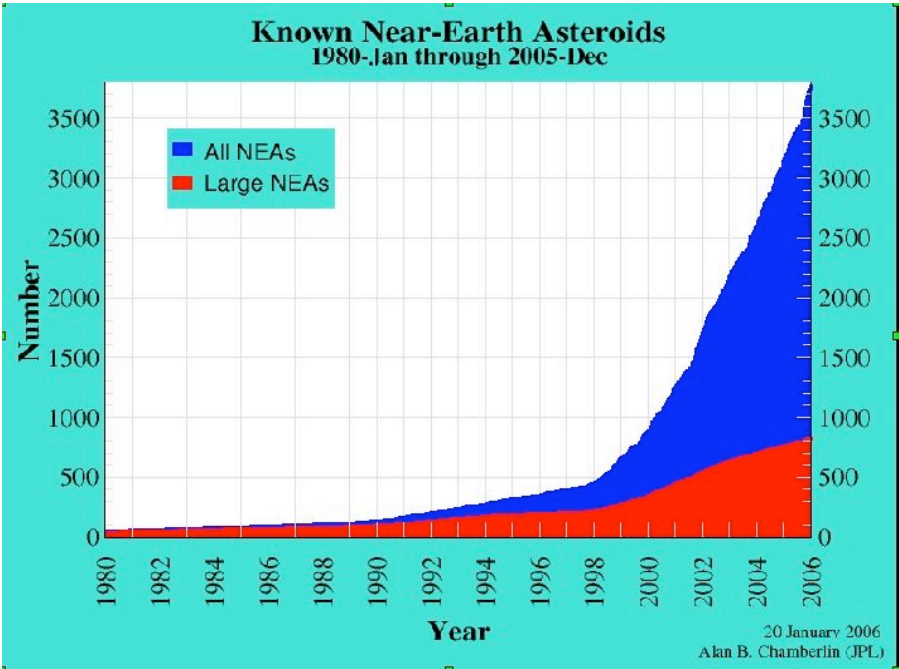


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Background



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Background



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## Asteroid Themes



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- 1. Enhance space exploration**
  - Resource utilization
  - Platform for transportation
- 2. Pursue scientific activities**
  - In situ or sample return missions
  - Investigate solar system origins
- 3. Understand and mitigate risk asteroids pose to Earth**
  - Detection and inventory
  - Impact prevention technologies
- 4. Cross-cutting themes consistent with lunar exploration**
  - Expand Earth's economic sphere
  - Strengthen and build global partnerships
  - Engage, inspire, and educate public

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## Asteroid Objectives



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- Material Processing (Beneficiation)
- Asteroid Resource Utilization
- Commercial Opportunities
- Power
- Communication
- Global Partnership
- Public Engagement and Inspiration
- General Infrastructure
- Program Execution
- Operations Test & Verification
- Astronomy and Astrophysics
- Heliophysics
- Geology
- Life Support and Habitat
- Environmental Hazard Mitigation
- Surface Mobility
- Operational Environ Monitor
- Crew Activity
- Transportation

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## Issues & Enablers



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- **Legal**
  - International treaties
  - Jurisdiction to allocate usage and access rights
- **Environmental**
  - Minimal environmental requirements
  - Abolish biological contamination requirements
- **Technological**
  - operate in the asteroid environment
- **Security**
  - Detect and deflect asteroids
  - Natural or human-altered trajectories
- **Economic**
  - Anchor tenant for asteroid derived products.

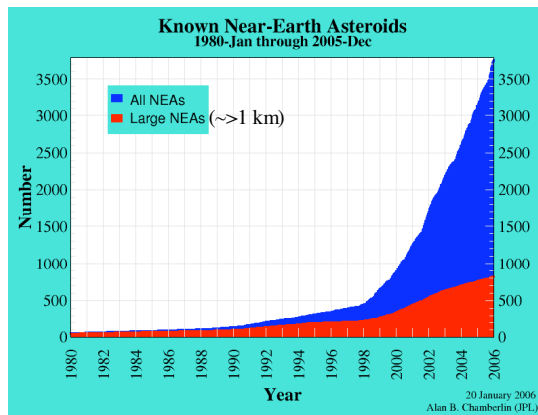
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## Action Items

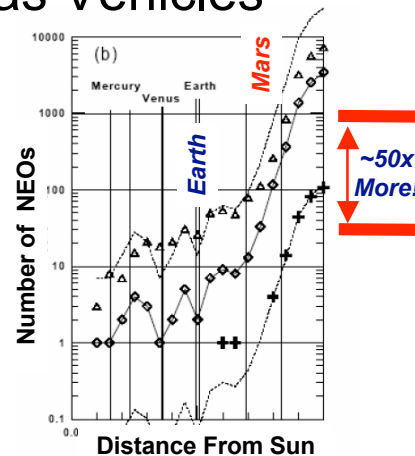


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- **Science and Technology**
  - Impact Hazard and Response Analysis
  - Resource Utilization Proof of Concept
  - Demonstrate Asteroids as Vehicles



*The more we look, the more we will find....*



*And it gets more intense at Mars*

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## Action Items

### • Education and Public Outreach

- Student Lead Asteroid Mission
- Centennial Challenge Category
- Young Professional Advisory Panel



Charles Lindbergh/Spirit of St. Louis: \$25,000 for first non-stop flight between Paris and New York.



Burt Rutan/SpaceShipOne: Winner of the \$10M, suborbital space flight X PRIZE.

*Asteroids are a logical next challenge!*



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## Asteroids as Transport



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# Cis-lunar Working Group Report

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























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## Cis-Lunar Working Group

### Part of the Next Generation Exploration Conference

### Declaration

*Space agencies are committed to the “safe, sustained, affordable human and robotic exploration of the Moon, Mars, and beyond.” However, we recommend that they explicitly define our ultimate goal and motivation in order to portray a sense of purpose to the public. Our goal is sustainable human settlement of the Moon and Mars and our motivation is to preserve the human race. All secondary exploration and science objectives flow from this main goal and are still imperative to our success. As an economic guiding principle, governments should be limited to those areas where only government can perform the activity and should recognize and coordinate with the larger private and military sectors. Also, space agencies must continue to fund the interdisciplinary science necessary to characterize environmental hazards associated with dust, radiation, surface charging, topology, and meteorites in order to make our first attempts at extraterrestrial living viable.*

#### 1.0 Introduction

#### 2.0 Themes

- 2.1 Prepare for future human and robotic missions to Mars and other destinations.
- 2.2 Pursue Scientifically-driven Activities
- 2.3 Extend Human Presence to the Moon to Prepare for Settlement
- 2.4 Expand Earth’s Economic Sphere to Encompass the Moon
- 2.5 Strengthen existing and create new global partnerships
- 2.6 Engage, Inspire, and Allow the Public to Participate in Space Exploration

#### 3.0 Objectives

- 3.1 Settlement
- 3.2 Expanding the economic sphere

#### 4.0 Key Recommendations

- 4.1 Lunar Exploration Program for the Survival of Humanity
- 4.2 Fund Interdisciplinary Lunar Science
- 4.3 Focus more on Global Partnerships
- 4.4 Focus on Areas Where Government is Needed the Most

#### 5. A Potential Future for Lunar Settlement

- Phase I: The assessment period
- Phase II: The adaptation period
- Phase III: Expansion period

#### Conclusion

#### 1.0 Introduction

The Cis-Lunar working group defined its charter to be the Earth-Moon system, including the activities conducted off-Earth and on the Moon. The Exploration Systems Mission Directorate (ESMD) within NASA, and possibly and other space agencies, are committed to the “safe, sustained, affordable human and robotic exploration of the Moon, Mars, and beyond.” We encourage governments to explicitly define the ultimate goal and motivation in order to portray a sense of purpose to the general public. Our ultimate goal is human settlement beyond Earth; our motivation is to ensure human survival.



This task is beyond the remit of space agencies and thus the private sector should be engaged, and exploration of possible forms of inclusions/cooperation should be prioritized. The ultimate goal of settlement and intermediate goal of exploration are enabled by including other actors such as the private sector in co-developing and co-maintaining a Cis-Lunar infrastructure.

This chapter outlines the themes for Cis-Lunar exploration, and explores the symbiotic relationship between the goal of settlement and commerce in the objectives section. Further, we outline four specific recommendations then describe in detail a potential future for a permanent human presence on the Moon extending the civilization off-Earth.

## **2.0 Themes**

This section outlines the proposed changes and additions to the exploration themes modeled after the draft version of the interim lunar exploration strategy provided to NGECC for comment.

### *2.1 Prepare for future human and robotic missions to Mars and other destinations.*

Reduce the risks and increase the productivity of future missions in our solar system by testing technologies, systems, and operations in an off-Earth planetary environment. Using the Moon as a test-bed for Mars will help us learn how to explore. The initial settlement of the Moon will provide technology for future exploration and a template for future settlements.

### *2.2 Pursue Scientifically-driven Activities*

Engage in scientific investigations to address fundamental questions about the solar system, the universe and our place in them by:

- *Of the Moon:* Study the history of the Moon and the current lunar environment and structure to learn about the evolution of our solar system;
- *On the Moon:* Understand the effects of the lunar environment on terrestrial life and the equipment that supports lunar inhabitants;
- *From the Moon:* Use the Moon as a platform for performing scientific investigations that are uniquely enabled by being on the lunar surface, including observations of the Earth and other celestial phenomena.

### *2.3 Extend Human Presence to the Moon to Prepare for Settlement*

Develop the knowledge, capabilities, and infrastructure required to live and work on the Moon, with a focus on sustainable growth of:

- The duration of time that individuals can live safely on the Moon;
- The number of individuals that can be supported on the Moon;
- The level of self-sufficiency of operations on the Moon;
- The characterization, utilization, and commercialization of lunar resources;
- The degree of non-governmental activity.

The long-term survival of the human species will be greatly increased by backing up the biosphere with permanent settlements on the Moon and other locations. This will help to reduce the probability of the demise of human civilization due to a catastrophic event such as the impact of a large asteroid, nuclear war, climate change, or biological weapons.

### *2.4 Expand Earth's Economic Sphere to Encompass the Moon*

Create new markets, based on lunar and Cis-Lunar activity that will return economic, technological, and quality-of-life benefits to all humankind.

1. Involve private and commercial interests to the maximum extent possible; initially by purchasing services (transportation, propellants, etc), and eventually transitioning operations of infrastructure to private parties.

2. Sustain a human presence beyond Low Earth Orbit by mobilizing resources through a working public-private mix of space investments into Cis-Lunar infrastructure and resource utilization leading to economic return (in the broadest sense) and reinvestment.

### *2.5 Strengthen existing and create new global partnerships*

Enhance global security by increasing international cooperation via transparent activities of space agencies and shared responsibility and redundancy of space exploration activities.

### *2.6 Engage, Inspire, and Allow the Public to Participate in Space Exploration*

Use a vibrant exploration program to inspire the public through outstanding human achievement. Excite the public about space exploration while educating them about the benefits of exploration. Encourage students to pursue careers in high technology fields, and ensure that individuals enter the workforce with the requisite scientific and technical knowledge and enthusiasm necessary to sustain exploration. Make space more relevant to the lives of people today by creating meaningful science and exploration activities for the public to participate in global exploration activities.

## **3.0 Objectives**

As a result of our discussion, we recommend that the following two objectives have more emphasis: the first focusing on settlement, and the second expanding the economic sphere. These objectives should be thought of as a reinforcing system as both are enablers of the other.

### *3.1 Settlement*

While the meaning of our existence in the universe is debated, the need to protect it is not. As long as humans remain confined to a single planet, there is a possibility that a catastrophic event could end civilization. Such events include a global disease pandemic, asteroid or comet impact, and nuclear war, among others. Extending human civilization to space could enable our species to avoid certain such disasters and thus increase the probability of survival. The long-term survival of the human species will be greatly increased by backing up the biosphere with permanent settlements on the moon and other locations.

### *3.2 Expanding the Economic Sphere*

With agency budgets fixed over the coming decade, in order to enable space agencies to focus their efforts on science and exploration, and to mobilize more resources for the Lunar Exploration Program, the private sector should play a larger role and be incorporated early on in the definition of the program. This means new forms of public/private relationships need to be stimulated. In addition, as an enabler of permanent settlement on the Lunar surface, a legacy of the Lunar Exploration Program could be new commercial opportunities

and new economies coming the infrastructure and proof of principle of space commerce demonstrated by our envisioned Lunar Exploration Program, based on exploitation of Cis-Lunar resources.

Thus, we recommend greater focus on the role of the private sector in the Program, not only for enabling the program itself, but in view of the legacy of the program, to go beyond planting flags but to stimulate a sustainable human presence in Cis-Lunar space with the possibility of new economies (based on space resource exploitation) with wealth creation feeding back to Earth but also providing a platform for venturing further into the solar system, not only technological capability but a proof of viability of space commerce and resource exploitation beyond LEO.

## **4.0 Key Recommendations**

### *4.1 Lunar Exploration Program for the Survival of Humanity*

Survival of humanity needs to be explicitly stated as reason for settlement in “settlement theme” and as overarching reason for “Why are we going to the moon?” Settlement, or the evolution of human civilization, dictates the evolution of the program at the beginning and enables all other objectives.

### *4.2 Fund Interdisciplinary Lunar Science*

To achieve sustainable Space Exploration, government sponsored space agencies should fund cross-interdisciplinary (CID) science. This is particularly important for scientific investigations of the lunar dust, and other aspects of the lunar environment, to understand the effects of the lunar environment on terrestrial life and the equipment that supports lunar inhabitants. In addition, funding opportunities for lunar science should be similar to the Mars program. Governments should be funding low Technology Readiness Level projects to help advance them to flight capability. Explore the use of the Moon as a platform for performing scientific investigations that are uniquely enabled by being on the lunar surface, including observations of the Earth and other celestial phenomena.

### *4.3 Focus more on Global Partnerships*

Space agencies and companies should promote international exchange of staff. Similar to the scientific communities’ ability to transcend boundaries for the pursuit of knowledge, explorers would be greatly enabled by diminishing national laws that prohibit the coordination and exchange of needed information. Furthermore, complementary but independent missions will yield significant scientific discoveries while minimizing risk on the critical path.

### *4.4 Focus on Areas Where Government is Needed the Most*

The role of publicly funded organizations must shift and focus on specific areas of the Lunar Exploration Program, rather than trying to do everything themselves. Agencies should recognize capabilities of private industry, and transfer as many tasks as possible / feasible from agency to industry. This could encourage / stimulate the growth of new industries and markets and transition what would previously be government constructed and run facilities into the private domain. This evolution will ensure evolving exploration goals, as agencies focus efforts on science and exploration.



## 5.0 A Potential Future for Lunar Settlement

Human presence on the moon could be divided into three phases of evolution. In Phase I, humans reach the moon and are supported by the resources they carry from Earth. This is the *assessment period*, where the target locations for sustained human presence are identified, temporary habitats are built, and the requirements surviving on the moon autonomously are determined. In Phase II human existence on the moon becomes self-sustaining. This is the *adaptation period*, where all critical systems become fully sustainable using only resources and infrastructure currently available on the moon. In Phase III, the technology for developing duplicate lunar bases is created. This is the *expansion period*, where re-habitation is possible without support from the Earth.

	2006	2010	2018	2022	2027	2037	2045 →
Pre-Human	Orbiters						
	site selection						
		landers/rovers					
		environmental characterization					
		engineering demonstration					
Phase I			*First Manned Landing				
			Sortie Missions- Phase I				
			Development- Phase I				
				Production- Phase I			
Phase II					Operation- Phase I		
					Development- Phase II		
						Production- Phase II	
Phase III							Phase III Begins →

### Phase I: The Assessment Period

(weeks – months, 2 – 5 people):

1. Installation of a temporary lunar communication network
2. Rover-based site selection
  - a. Environmental characteristics
    - i. ground bearing strength
    - ii. regolith resources
    - iii. radiation
    - iv. solar energy
    - v. landing obstacles
  - b. Power options
  - c. Communication options
  - d. Mobility limitations
  - e. Scientific objectives
3. Installation of an initial habitat
  - a. Combination of in-situ and earth resources
  - b. Considering the essential elements
    - i. Oxygen

- ii. Water
- iii. Food
- iv. Energy
- v. Communication
- 4. Rover based surface exploration
- 5. Implementation of short-term science objectives
- 6. Demonstration of future technologies
  - a. Dust mitigation systems
  - b. All-terrain rovers
  - c. Regolith processing systems
  - d. Radiation shielding systems

### *Phase II: The Adaptation Period*

(0-10 years, 2 – 10 people):

1. Establish in-situ resource utilization systems
  - a. Oxygen
  - b. Water
  - c. ...
2. Making the lunar communication network more robust
3. Establish a persistent energy source
4. Development of a lunar “green house”
5. Development of a lunar medical care facility
6. Development of systems maintenance tools
7. Development of a “last resort” system for returning to Earth

### *Phase III: Expansion Period*

(permanent, 10 – 100 people):

1. Base replication
2. Space exploration from moon

## **Conclusion**

We encourage governments to explicitly define the ultimate goal and motivation in order to portray a sense of purpose to the general public. Our ultimate goal is human settlement beyond Earth; our motivation is to ensure human survival. This task is beyond the remit of space agencies and thus the private sector should be engaged, and exploration of possible forms of inclusions/cooperation should be prioritized. The ultimate goal of settlement and intermediate goal of exploration are enabled by including other actors such as the private sector in co-developing and co-maintaining a Cis-Lunar infrastructure.

Public participation (rather than outreach) is important for success. Thus interaction fora such as public debate and consensus conferences, ‘public participation’ (the participation of the public directly in missions), as well as more standard outreach mechanisms should be invested in and framed as a core activity.

# Cis-lunar

Everything within the  
Earth-Moon system

## Core themes

- Environmental Characterization
- Policy & Outreach
- Settlement
- Economic & Commerce



## EXPLORATION SYSTEMS MISSION DIRECTORATE

*Safe, sustained, affordable human and robotic  
exploration of the Moon, Mars, and beyond...*

To achieve this vision for space exploration,  
NASA must fund cross-interdisciplinary (CID)  
science...

### Environmental Hazards:

- -Dust
- -Radiation
- -Surface Charging
- -Topology
- -Macro-meteorites

### CID Science:

- Biology
- Materials
- Electronics
- Heliophysics
- Geology

## Science recommendations

- **funding** opportunities for lunar science should be similar to the Mars program.
  - Perhaps a common planetary funding system
  - Shouldn't be Mars vs everything else
- government should **fund** low TRL
  - Advance it to flight levels
  - Who else but government can fund this?

## Outreach recommendations

- Identify technology transferred to daily life.
- Scientists & Engineers involved in public outreach
  - Partner with student internships, volunteer organizations, etc
- Educate media correspondents so they can accurately report on space
- Use new media outlets that showcase spaceflight:
  - YouTube, Podcasts, Astronaut blog
  - show the human side!
  - Annual “State of Space” DVD

## Global Partnerships

- Promote international exchange of staff
  - similar to current scientific collaborations
  - eliminating or severely reducing ITAR restrictions
- Complementary but independent missions
  - provide significant scientific yield
  - with minimal risk to fellow partners (no weak link)

## Economic Guiding Principles

- Government role must be limited to only those areas where there is irrefutable demonstration that only government can perform activity
- Implement and recognize larger private industry
- Specific goals:
  - industry to have primary role of providing services
  - foster new markets and commercial opportunities

## Economic Theme Revisions

- Expand Earth's economic sphere to encompass the Moon
  - Pursue lunar activities with direct benefits to life on Earth.
- Involve private interests to the maximum extent possible
- Government to purchase services initially
- Transition operation of gov facilities to private interests
- Ensures evolving exploration goals



## Spreadsheet Revisions

- Greater outsourcing of required cis-lunar capabilities
  - Transportation
  - Power
  - Habitation
  - Research
- Encourage growth of new industry and markets
- Protect IP for researchers on government lunar facilities

## Settlement

- Themes Document *Lacks description of WHY*
  - Reason for settlement is the long-term survival of the human species...
- To accomplish settlement, make it the primary requirement!
  - Dictates evolution of program from beginning
  - Enables all other objectives

## Settlement Phases

Phase I: Sorties	Phase II: Self-Sustainability	Phase III: Expansion
Installation of temporary communication network	Persistent, reliable power source	Ability to create new bases on moon
Rover based site selection	Ability to grow and process food, and extract water, and oxygen	Permanent settlement
Installation of initial habitat	Installation of permanent communications network	Lunar based solar-system exploration
Rover-based surface exploration	Ability to service and maintain all equipment	




# Earth 3.0

## Working Group Report

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**Earth 3.0 Working Group**  
**Terrestrial Motivation for Continued Exploration of Space**  
Part of the Next Generation Exploration Conference

**Declaration**

*We affirm the principle that a viable human space exploration program must be conducted hand-in-hand with a comprehensive scientific research program that incorporates both the physical and life sciences and that continues to protect and extend understanding of our home planet. Without advances in life science, we will be incapable of devising self-sustaining extraterrestrial habitats, and we will struggle to survive on the only living planet we know. Without advances in the physical sciences, we limit our ability to imagine new technologies for space travel and to understand the nature of the universe we explore. Scientific advances expand the boundaries of humanity's dreams.*

**1.0 Introduction**

- 1.1 Definition of a Earth 3.0:
- 1.2 Definition of "Sustainable"
- 1.3 Current Applications of Earth 3.0 Concepts

**2.0 Themes: The Space Exploration Initiative and Earth 3.0**

- 2.1 To Explore is Innately Human
- 2.2 Pursuing Scientific Activities to Address Fundamental Questions About the Solar System, the Universe, and Our Place in Them
- 2.3 Foster Creation of Human Communities on the Moon
- 2.4 Expanding Earth's Sphere of Influence Sustainably
- 2.5 Engage, Inspire, and Educate the Public

**3.0 Objectives: What must be done to create Earth 3.0?**

- 3.1 Basic Life Science Research
- 3.2 Basic Physical Science Research
- 3.3 Earth and Space as a Continuum
- 3.4 Promote Inter-Agency Collaboration
- 3.5 Freedom of International Cooperation
- 3.6 How to Include Private Industry to make Earth 3.0 Economically Profitable
- 3.7 New Ways to Bring Science and Space to the Public
- 3.8 Preservation of the Space Environment

**4.0 Issues and Enablers: Are there devices of society that either impede or promote Earth 3.0?**

**5.0 Action Items: What can be realized now and what are the first steps to implementing Earth 3.0 on a larger scale?**

- 5.1 Contract Private Companies to Make Popular Educational Programming
- 5.2 Offer Large-Scale Centennial Challenges

**1.0 Introduction**

If not for basic scientific curiosity about the unknown, the Moon would still be known as a supernatural phenomenon rather than a destination. Scientific curiosity drives the continued improvement of living conditions, starting with the industrial revolution that

began after the Renaissance. However, humans of the 21st century are unique in that we are conscious of our capability to change, expand, and sustain our environment, which includes our attitudes, laws, technology, and global community. Consequently, the actual and perceived space in which we roam has expanded.

The following document defines Earth 3.0, outlines the motivation for increased scientific inquiry, describes specific objectives, identifies issues and enablers for reaping benefits, and highlights what is currently being done, or may be done in the immediate future to further the concept of “Earth 3.0.” The following document is meant to be a summary of specific topics the authors felt most strongly pertained to the proposed definition of “Earth 3.0” – however, the reader must be cautioned that Earth 3.0 is a largely interpretive concept. As put by a member of the team, “We are challenged, if not crippled, by our lack of communication that relays meaning, rather than vocabulary.”

### *1.1 Definition of Earth 3.0*

Earth 3.0 represents the state of planetary affairs in the coming possible futures. Exploration and its associated scientific, economic, and ethical issues will have a major impact on society; therefore, there is a need to understand what could happen, what is likely, and what is desired. Technologies, economies, and ideas of Earth 3.0 are those that are considered desirable. In that regard, Earth 3.0 represents the end, for which space is a means.

### *1.2 Definition of “Sustainable”*

Sustainable, as used in this documents, is defined as those systems (technological, biological, et al.) whose consumables are replenished at the same rate of consumption, or utilize otherwise wasted resources, such as wind and solar. Sustainable systems may be operated indefinitely; sustainable economies and societies are those which may persist indefinitely.

### *1.3 Current Applications of Earth 3.0 Concepts*

There already exist many examples of Earth 3.0 concepts. Whether by coincidence or design, such concepts are already part of the US space program, including but not limited to the regular use of fuel cells and solar power for space vehicles, and regulated land utilization along the Canaveral National Seashore. Another interesting application of Earth 3.0 is “future studies”. Future studies are a means for describing what possible futures lie ahead, based upon careful study of past and current trends. Future studies are useful guides to determining the best course of action based on potential outcomes. Further detailed discussion of Earth 3.0 applications can be found in the objectives section.

## **2.0 Themes: The Space Exploration Initiative and Earth 3.0**

### *2.1 To Explore is Innately Human*

Simply put, many existing themes regarding space exploration are justifications rather than reasons to send humans to the Moon and Mars. Often times, excess focus is spent pushing benefits from “spin-offs” and technological benefits. The psychological and societal benefits of knowing humanity is capable of going to, and sustaining a society in the cosmos is just as important, if not more important, than the technological benefits of space travel.

### *2.2 Pursuing Scientific Activities to Address Fundamental Questions About the Solar System, the Universe, and Our Place in Them*

Study of the Moon and current lunar environment and structure will help us learn more about the evolution of our solar system. Understanding long-term effects of the lunar environment on terrestrial life and equipment is a necessary step before embarking on longer, more complex mission to Mars. The moon is also an ideal platform for performing scientific investigation of the Earth and celestial phenomena.

### *2.3 Foster Creation of Human Communities on the Moon*

A lunar community must be created in order to develop the knowledge, capabilities, and infrastructure required to live and work at extraterrestrial locations. The goal of a lunar community would be to develop sustainable growth of:

- the number of individuals the community can support
- duration which humans can stay
- commercialization of lunar resources
- self-sufficiency of lunar operations
- non-governmental activity

The need for lunar self-sufficiency is analogous to the terrestrial need for self-sufficiency. Commercial incentive to develop such technologies already exist, and would be increased from extraterrestrial exploration needs.

### *2.4 Expanding the Earth's Sphere of Influence Sustainably*

Long-term, cis-lunar activity will create new markets that will return economic, technological, and quality-of-life benefits to humankind.

### *2.5 Engage, Inspire, and Educate the Public*

Use an existing vibrant exploration program to excite the public about space, encourage students to pursue careers in high-technology fields, and ensure that individuals enter the workforce with enthusiasm and the requisite scientific and technical knowledge necessary to sustain exploration. The latter should be backed by career opportunities in industry and academia that can also provide short-term and tangible successes and results for the workforce. The average new workers of today are interested in seeing near term results (i.e. within years, versus decades).

## **3.0 Objectives: What must be done to create Earth 3.0?**

### *3.1 Basic Life Science Research*

Summary: While the long-term space exploration objectives are technologically feasible, current understanding of human and biological factors is insufficient to carry out a manned Mars mission. Further research is needed in the following areas:

- self-sufficient engineered ecosystems
- bone and muscle loss
- immune system effects
- genetics and radiation countermeasures
- psychological effects on groups/individuals

Failed attempts to engineer self-sufficient, closed biologic systems that mimic the Earth's ecosystem should serve as a warning that we do not fully understand how our planet's ecosystem works. A funded effort to engineer a truly self-sufficient, closed ecosystem should be a top priority.



Value: The advance of self-sufficient, micro-scale environments represents a more comprehensive understanding of life itself. Such an advance would result in a more robust management of currently uncontrollable biological factors, improving capabilities in disciplines ranging from agriculture to medicine.

### *3.2 Basic Physical Science Research*

Summary: Physical science describes the most fundamental properties of matter that makes up the universe around us. Physical science research expands fundamental capabilities in all scientific disciplines; however, basic science is unprofitable for private stakeholders due to a lack of short-term investment return. However, due to the omniscient benefits to society, responsibility lies in the government to allocate adequate funding for research into basic science.

Value: Research into basic science yields greater knowledge and, subsequently, greater technology. For example, research into nuclear physics may eventually produce a more efficient reactor. A greater understanding of chemistry will provide for advances in biology and medicine. A more in-depth comprehension of the basic sciences will increase our insight in all areas.

### *3.3 Earth and Space as a Continuum*

Summary: Popular belief has always held that Earth and space are separate entities. In reality, both are part of a continuum. One important point of the Earth 3.0 concept is the fact that we can look back and examine ourselves as a species; this unique capability must be utilized.

Value: The conception of a separate Earth and space is detrimental because it confines our presence in space to the status of “visitor”. The “Spaceship Earth” idea is a useful visualization because it brings to light the fragility of our environment, and our need to protect it for the future of our children, and the perpetuation of the human species.

### *3.4 Promote Inter-Agency Collaboration*

Summary: NASA’s human space exploration program should follow the recommendations of the National Research Council and National Academy of Sciences, and expand space sciences to other research bodies, such as the National Institutes of Health, the Department of Agriculture, and the National Science Foundation.

Value: Complexity of the challenges that must be overcome to execute a successful exploration program makes space, by nature, an attractor for thinkers of all disciplines.

### *3.5 Freedom of International Cooperation*

Summary: While the global political climate invariably changes, the challenges of space do not. Just as space has been shown to be an attractor for the greatest minds from a spectrum of disciplines, it should be inclusive of great minds from all backgrounds.

Value: The global community benefits from space exploration, therefore the effort should be made to maximize the capabilities of the space program by permitting the most competent individuals to contribute.

### *3.6 How to Include Private Industry to Make Earth 3.0 Economically Profitable*

Summary: In order for the space industry to truly progress, the private sector must become more involved. So long as this industry remains dominated by government agencies, it will be crippled by bureaucracy, paperwork, and lack of funding. Activity in the private sector will encourage competition and the progression of better, less expensive technology.

Value: Commercial activity in space will provide more general access to space for all.

### *3.7 New Ways to Bring Science and Space to the Public*

Summary: One of NASA's missions is to communicate scientific knowledge. Since the space program is driven by the public's interest, a more effective way of reaching a constantly-changing audience is needed. Television shows that colorfully explain technical subjects have already been found to be highly successful – why not contract similar private entertainment corporations to produce shows on the work that NASA is already doing?

Value: There is a distressing lack of scientific literacy among a broad demographic of Americans. It is in the nation's best interest to promote and develop scientific and technological leadership. By reaching a larger audience through more relevant programming, NASA can promote this change.

### *3.8 Preservation of the Space Environment*

Summary: One problem of particular interest was the problem of space debris, commonly referred to as space junk. Unchecked, the possibility exists that the collision between two orbiting objects could start a chain reaction, rendering access to space impossible. Because there is currently no practical way to eliminate space debris, it is an absolute necessity that no more debris is created.

Value: The preservation of space is something that all professionals in the space industry must take ownership. The multitude of benefits we reap from space must be protected.

## **4.0 Issues and Enablers: Are there devices of society that either impede or promote Earth 3.0?**

The goal of space exploration is a large one that must be supported by society as a whole. While the benefits of space exploration are widely recognized, there are many other issues that society must deal with on a daily basis. Keeping these things in mind, the following list identifies particular challenges which impede the implementation of Earth 3.0:

- Economic conditions may force governments to cut civilian R&D funding
- Economic conditions may slow the growth of the private space industry
- Lack of understanding may cause uninformed opposition to scientific inquisition meant to improve the lives of everyone
- The perception that Earth and space are separate entities
- Shutdown of Low Earth Orbit access to space due to space debris
- Current lack of understanding how to sustain self-contained ecosystems
- Inertia to change from traditional, non-sustainable energy systems
- Unsustainable urban sprawl and deforestation
- Unsustainable population growth
- Apathy of individuals to take ownership of the Earth they will pass on to their

children

- A more effective means of communication that stresses meaning, rather than vocabulary, is needed
- Under-representation of non-technical communities, such as the arts and humanities, may reduce NASA's ability to communicate with the public

While all of these things represent potential roadblocks, nearly all of the above items can be solved with effective outreach programs that excite and educate the public.

Similarly, certain trends in society are conducive to developing Earth 3.0 in support of space exploration. These include:

- A very strong technically competent domestic work force
- Existing acknowledgement of the so-called energy crunch
- Generally high support of domestic space exploration programs
- A large number of willing and capable international partners
- A huge quantity of currently underutilized, renewable global resources
- The human desire to improve quality of life

If NASA can continue to inspire all generations to learn about science and technology, then the vision of space exploration and Earth 3.0 may be realized.

## 5.0 Action Items: What can be realized now and what are the first steps in implementing Earth 3.0 on a larger scale?

The potential of Earth 3.0 technologies has yet to be realized. Without a significant change on every individual's part, engineers, scientists, and public officials can create a world in which the quality of life continues to improve *in perpetuum*, motivated by the space program. To do so, a few objectives may be worked on immediately.

### 5.1 Contract Private Companies to Make Popular Educational Programming

When the Mars rovers landed, NASA's website was on the list of top 10 most visited websites on the internet that week – the public has already shown NASA that they are interested – “Give the people what they want.” Times have changed; America is no longer a “starch-and-tie” society. Outreach programs should reflect the times in order to capture the attention of as many citizens as possible.

- Potential exists to capitalize on the popularity of “reality” TV shows – a miniseries about life on the ISS would likely be a big hit
- The idea is to feed minds with scientific knowledge: prime-time programming is the prime opportunity to reach and educate a large fraction of the population
- Invite artists, writers, storytellers, and other non-technical individuals to NASA conferences and events to gain outside perspectives and promote NASA projects
- Sell independent entertainment companies on the idea of making television shows about the inspiring and interesting work that NASA does on a daily basis

### 5.2 Offer Large-Scale Centennial Challenges

In the past, NASA's Centennial Challenges have been smaller-scale projects, but are continually increasing in size and complexity. One idea is to allocate a portion of NASA's budget for large-scale Centennial Challenges. Innovative concepts, such as “A Dollar to the Moon,” could be devised, where companies would compete to design and build a rocket

capable of carrying a crew to the moon on \$300M dollars, equivalent to about one dollar for every citizen (reference what Scaled Composites built to win the comparatively small \$10M X-Prize). If this project were integrated with a prime-time television series, public interest in science and technology would surely rise, giving NASA the opportunity to educate millions of viewers.

In the end, the goal of the space program is to inspire the next generation to continue expanding scientific understanding and development, which in turn will improve the quality of life for every person on the planet: Earth 3.0.



# Earth 3.0 Working Group



## Next Generation Exploration CONFERENCE

Emerging global space leaders designing  
the future of space exploration.

**August 16 - 18, 2006**

NASA Ames Research Center • Building 3

## Introduction



**Earth 3.0 is the next step  
in the evolution of humanity.**

**For the first time in history, humans can  
see our capability to effect change and  
expand and sustain our environment,  
including our attitudes, laws,  
technology, and sense of community.**

**Consequently, the actual & perceived  
space  
in which humans roam has expanded.**



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## Findings & Recommendations on Global Exploration Strategy



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- **NASA needs to carry out the recommendations made by NRC, Next Generation of Space Explorers, and similar advisory bodies**
- **Require key NASA decision-makers to participate in our discussions of vision and future policy**
- **Maintain a standing advisory board to report to top NASA administration on a quarterly basis**
- **Make sustainability of human-nature interaction a fundamental principle of space exploration**
- **Engage other federal agencies to leverage research and development for critical Earth-space technology**
- **Contract public outreach to independent entertainment companies to engage a more general audience**

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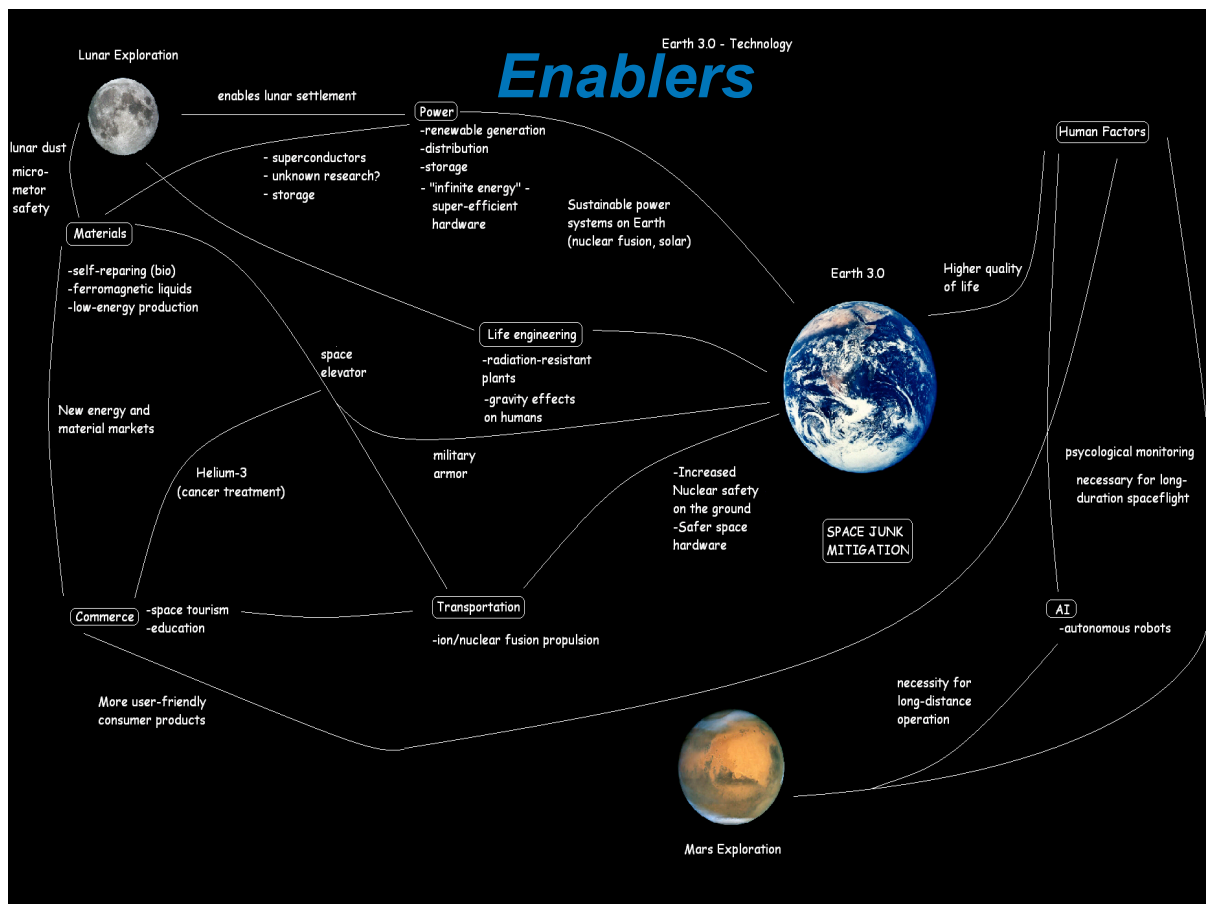
## Cis-lunar Themes



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- **Core Theme #0 (currently missing):** To explore is innately human. *Why? Existing themes are justifications, not reasons for going to the Moon & Mars.*
- **Core Theme #1:** Use the Moon as a testbed for Mars *only* where applicable. *Why? Gives the false impression that we can't go to Mars without going to the Moon.*
- **Core Theme #3:** Extend human civilization to other planetary bodies with the Moon as the first step. *Why? We don't want settlements; we want civilization.*
  - Drop last bullet; *redundant*
- **Cross-cutting Theme #2 (description):** Unite nations in collaborative pursuit of common objectives by providing a challenging, shared and peaceful global activity. *Why? "global security" is vague and can be misinterpreted.*

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## Issues



- Throughout the conference, it became apparent that we are challenged, if not crippled, by insufficient means of communication
- Abstract ideas and bold visions of the future are all-to-easily discounted as sci-fi storylines or buzzwords - triggering automatic reactions that dismiss even the most profound ideas
- Development of a means to formulate a grand and bold vision, in a forum without immediate judgment or dismissal based on poor phraseology, is critical to nurture future NASA leaders, and encourage them to consider all possible futures
- Non-science and engineering disciplines (arts and humanities) should be represented among lunar astronaut community

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## Action Items



***The next generation of explorers have a vested interest in ensuring the boldest vision of our future as a space-faring society, we propose to meet twice yearly to:***

- ***Evaluate potential outcomes associated with NASA's current direction in the context of a broad and long-term vision***
- ***Envision other desirable future outcomes***
- ***Propose specific near-term actions to enable desirable future outcomes***
- ***Actively engage NASA decision makers***

***One of our recommendations is to add the focus on Earth back into our vision statements***

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## Earth 3.0 Declaration



***We are creating an environment that fosters daring thinking and bold action that is consistent with the limitless spirit of exploration.***

***Space is inclusive of Earth***

***Nothing should stop us from dreaming forward***

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## Conclusions



- For the first time in history, humans can see our capability to effect change and expand and sustain our environment, including our attitudes, laws, technology, and sense of community.
- The Next Generation of Space Exploration – Earth 3.0 working group has found a lack of representation from science and humanities – the consensus is that these groups are needed in the discussion future of space exploration.
- NASA needs to actively work to change the perception that humans are separate from nature, and Earth is separate from space – they are one and the same
- Sustainability is key to human survival on Earth and in Space


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# Mars Science and Exploration Working Group Report


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


















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**Mars Science and Exploration Working Group**

Part of the Next Generation Exploration Conference

**Declaration**

*In Mars, the spirit of exploring an exciting and rewarding new frontier is alive. Mars not only offers a unique destination for exploration, but it is also a critical destination for the advancement of human society and preservation of humanity. The exploration of Mars will provide significant social and technological benefits to enhance life on Earth as well. International cooperation will not only be essential to the success of a human presence on Mars, but development of such interactions will jumpstart collaboration on global issues. The eventual commercialization of space holds tremendous opportunities for economic growth. Finally, there is an undeniable basic human need to explore and define our place in the universe. The overarching theme that ties together all of these reasons for exploration is to inspire and unite the global community to pursue a common cause that is much larger than disagreements over ethnic differences or national borders. Continuous inspiration of the public, the scientific community, and the community of Earth are required in order to explore Mars.*

**1.0 Introduction****2.0 Themes**

- 2.1 Societal benefit of Exploring Mars
- 2.2 Scientific benefit of Exploring Mars
- 2.3 Technological development benefits in Exploring Mars
- 2.4 Exploration as need for humanity
- 2.5 Economic benefits of Exploring Mars
- 2.6 The cross-cutting theme: inspiration and unity

**3.0 Objectives:**

- 3.1 Science
- 3.2 Society
- 3.3 Exploration
- 3.4 Technology Development
- 3.5 Economics

**4.0 Issues and Enablers**

- 4.1 Issues:
- 4.2 Enablers:

**5.0 Action Items:**

- 5.1 Political action
- 5.2 Inspiring our youth
- 5.3 Raise Public Awareness and Support
- 5.4 Raise Visibility through use of "virtual world" technology

### 1.0 Introduction

The following two questions were considered during the Mars Science and Exploration working group:

- (1) What are the compelling reasons for exploring Mars?
- (2) What activities are needed to enable a safe and productive Mars campaign?

Properly articulating the “why” of Mars science and exploration at a high level is an important starting point for this activity. The working group established five major themes (science, society, exploration, technology development, economics) and one overarching concept (inspiring and uniting humanity). Each of these themes are discussed in detail below. Recommendations are kept at a high level so that they might remain relevant throughout the lifetime of the program. For example, specific scientific objectives were outlined since it was determined that those details are adequately being assessed by various other science working groups.

In order to achieve science and exploration goals on Mars, there are a number of activities that must be accomplished. There was a strong feeling among participants that great care must be taken to ensure that these activities are well-defined in advance and it is clear when objectives are met in order to move forward. The team felt that a well-defined and publicized plan would help space agencies and the public track progress and remain focused on the road to Mars and beyond. A clear plan will ensure that activities on the Earth and Moon enable ongoing scientific discovery and exploration outside of the Earth-Moon system.

### 2.0 Themes

Perhaps the foremost question regarding the exploration of the red planet is the justification behind the exploration itself. Much work has been done regarding what science can be achieved on the surface, as well as the necessary engineering challenges to overcome in order to allow humanity to extend its presence in the solar system. However, the more profound questions regarding why the Earth’s energy and financial resources should be spent on such an undertaking has, in the minds of the working group’s participants, not been addressed in a significant way.

The Mars Science and Exploration group at the Next Generation Exploration Conference has attempted to address this question. As a result, the motivations have been divided into five different categories, or themes, that will benefit humanity. These five themes—society, science, technology development, exploration, and economics—are linked with a fundamental cross-cutting, more philosophical theme: inspiring and uniting human society.

#### 2.1 Societal Benefit of Exploring Mars

Earth is currently challenged environmentally, socioeconomically, and by the potential threat of a large asteroid impact; each of these challenges could threaten the survivability of humanity. Human habitation of Mars would decrease the probability of extinction of our species, and promote and encourage the further spreading of humanity’s seed beyond its cradle.



As described previously, the exploration of the red planet would benefit not only the space-faring countries, but all of humanity, in the inspiration it would provide to youth, the international collaboration it would necessitate, and the economic returns it might provide to less-developed countries. As such, the space-faring nations have the societal responsibility to undertake the exploration of Mars for the benefit of all nations, including those that may not currently have the political, technological, or financial capabilities to do so.

### *2.2 Scientific Benefit of Exploring Mars*

Perhaps one of the most fundamental questions that humanity has been addressing since the dawn of consciousness is whether or not we are alone in the universe. In this early stage of the 3rd millennium, it is finally financially and scientifically feasible to seek out the answers to this ageless question. The search for a second genesis of life is within reach. Specifically, the astrobiological clues already discovered on Mars, such as past evidence of liquid water on its surface and potential methane in the atmosphere, make Mars the best laboratory outside Earth to potentially answer this question.

Because Mars is a planet that is less geologically active and has simpler atmospheric dynamics, it would serve as an ideal environment in which to perfect the tools needed to understand the much more complex dynamics of Earth. As such, characterizing the planetary systems of Mars (geology, hydrology, climate, glaciology, etc.) would enable the testing of terrestrial models on Mars to improve their outputs, and hence, predictions.

Whether or not humans can exist beyond the cradle of Earth is still unknown. The physiological response of human activity in different gravitational environments is not well understood. An outpost on Mars (and the Moon, as a precursor) would provide important data in understanding whether or not humanity is capable of sustained living off Earth.

### *2.3 Technological Development Benefits in Exploring Mars*

The engineering challenges necessary to accomplish human exploration of Mars will stimulate the global industrial machine and the human mind to think innovatively and continue to operate on the edge of technological possibility. Numerous technological spin-offs will undoubtedly be generated during such a project, and it will require the reduction or elimination of boundaries to collaboration among the scientific community. It will also foster the incredible ingenuity necessary to develop technologies required to accomplish something so vast in scope and complexity. The benefits from this endeavor are by nature unknown at this time, but evidence of the benefits from space ventures undertaken thus far point to drastic improvement to daily life and potential benefits to humanity as whole.

One example could come from the development of water recycling technologies designed to sustain a closed-loop life support system of several people for months, or even years, at a time, (necessary if a human mission to Mars is attempted). This technology could then be applied to drought sufferers across the world or remote settlements that exist far from the safety net of mainstream society.

### *2.4 Exploration as Need for Humanity*

Human beings are natural explorers. After having mapped the continents, it is only normal that our species looks beyond our sphere into the cosmos. Mars is particularly interesting as a new venture because of its first-order similarities with Earth.

### *2.5 Economic Benefits of Exploring Mars*

The effort to sustain a habitat on an environment inherently lethal to humans will require careful use of local resources. Such responsible use might spur new protocols in energy extraction/usage that could benefit terrestrial exploitation and thus improve the management of and prolong the existence of resources on Earth.

In the long term, commerce with Mars would create new enterprises between the planets, thereby increasing the economic sphere of Earth. Possibilities in tourism, advertising, the transport of raw materials, and improved energy methods are just a few of the many examples that will arise as the economy boosts on Earth.

### *2.6 The Cross-Cutting Theme: Inspiration and Unity*

The misunderstanding and miscommunication among people from different cultures and racial backgrounds are fundamental roadblocks that global society is dealing with in both yesterday's and today's socio-political situations. A global strategy, involving as many people on Earth as possible, must be put on the table to challenge humanity as a whole, which would require the world to collaborate for the successful realization of that event. A major point arising out of the working group's discussions is that international collaboration is not only vital to sending a human mission to Mars, ***but it should be one of the most important reasons for going in the first place.*** The exploration of Mars is undertaken with the idea of eventual settlement for preservation and expansion of the human presence into the solar system. In order to realize such a settlement, it is of extreme importance to think in terms of a "paradigm shift" in the current viewpoints of how the current global society is structured. The next generation of explorers, who will be responsible for the monumental undertaking of exploring the planet Mars, requires that the goal of uniting countries of the globe toward Mars exploration be considered with extremely high priority; it will be critical to involve all of humanity to achieve objectives that claim to be undertaken in the name of all of humanity.

Putting humans on the red planet will be an awe-inspiring event. The collaboration will be technological, educational, philosophical, cultural, and artistic. The international effort of putting humans on Mars will inspire future generations, and perhaps reprioritize global challenges resulting in a greater understanding and respect of our society

## **3.0 Objectives:**

### *3.1 Science*

The NGEC Science theme has five main objectives: 1) Search for past and present life including alternative life forms, 2) Characterize the planetary system of Mars by gaining knowledge of another planetary body in terms of geology, hydrology, climate, and other planetary properties, 3) Understand the history and evolution of our solar system through comparative planetology, 4) Determine human biological limits in particular the

physiological effects of long-term 1/3 G, and 5) Determine the Psychological and Sociology effects of long-term isolation and 1/3 G.

### *3.2 Society*

A human mission to Mars has the unique ability to establish and create many changes to society. NGEN suggests a human mission to Mars to be designed around the philosophy “of the good for all mankind.” The NGEN anticipates five main societal benefits from a human exploration of our Solar System, and in particular Mars: 1) Unite the international community under one common goal, 2) Understand humanity’s place in the Universe, 3) Human preservation and survivability, 4) Fulfill societies responsibility to explore, and 5) Foster a society promoting international cooperation on Mars.

### *3.3 Exploration*

Four main themes comprise the Exploration theme of the NGEN: 1) Inspire current and future generations to look beyond ourselves, our national borders, and our planet, 2) Establish human survivability, sustainable habitation, and long-term presence, 3) Satisfy the natural human desire to explore, and 4) Create a new perspective on humanity and Earth.

### *3.4 Technology Development*

Under Technology Development, the NGEN has two main objectives: 1) Enable sustained human habitation and long-term presence in space, and 2) Utilize spin-offs for Earth preservation and to identify alternative and new energy sources and infrastructures.

### *3.5 Economics*

The NGEN objectives under the Economics theme are: 1) Research new energy developments and resources, 2) Increase resource base and expand the economic sphere, 3) Create new employment opportunities, and 4) Foster commercialization opportunities.

## **4.0 Issues and Enablers**

### *4.1 Issues:*

**Sustained Funding:** In the past, exploration efforts have faded due to a lack of public interest. The cyclical nature of scientific and technology development funding is detrimental to sustaining a workforce, interest, and infrastructure.

**Restrictions to International Cooperation:** There currently exists a restrictive set of export controls that limit international cooperation in space science and engineering.

**Public Interest:** The public often overestimates the amount spent on space exploration and feels that it does not impact their own lives.

**Planetary Protection:** The difficulty of and regulations associated with planetary protection inhibit many scientific and exploratory goals. The additional resources required to adequately address many of the planetary protection regulations make some types of missions economically infeasible.

### *4.2 Enablers:*

International Traffic in Arms Regulations (ITAR): To engage the global community, it will be necessary to rework or dissolve the ITAR regulations.

Media: More education and communication with taxpayers could convince the public of the utility of space science and exploration.

Committee on Space Research (COSPAR): Review planetary protection protocols to focus on enabling exploration while protecting the pristine martian environment and potential subsurface ecology.

Milestones: Setting clear objectives and exit strategies for exploration will allow continued forward progress without being mired in the status quo. A globally recognized agenda will ensure interagency cooperation.

Commercial: A clear transition plan to commercial interests will allow the private sector to engage from the outset.

## **5.0 Action Items:**

In order to have a successful Moon-to-Mars mission, action must be taken now to gain the support of the global community. Things that can be done now to facilitate this are:

### *5.1 Political Action*

Write or speak to local politicians/representatives to gain their contemporaries' support of the Moon-to-Mars mission.

### *5.2 Inspiring Our Youth*

Inspire the younger generation's interest in the Moon-to-Mars initiative through speaking at conferences, giving presentations to elementary through post-secondary institutions and youth organizations, and organizing programs to educate and excite students.

### *5.3 Raise Public Awareness and Support*

Publicize the goal through writing papers to be included in newspapers, magazines, and online publications.

### *5.4 Raise Visibility Through Use of "Virtual World" Technology*

Utilize contemporary media sources, such as YouTube, MySpace, and Podcasts, to raise visibility for the Moon-to-Mars initiative.



# Mars Science and Exploration Working Group



## Next Generation Exploration C O N F E R E N C E

Emerging global space leaders designing  
the future of space exploration.

**August 16 - 18, 2006**

NASA Ames Research Center • Building 3

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# Mars Science and Exploration Introduction



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## • Why Mars?

- Crosscutting Theme: Inspiring and Uniting
- Science
- Societal Benefits
- Exploration
- Technology Development
- Economic Benefits

## • Pre-Mars

- Clear, distinct Moon-to-Mars plan
  - Long-term lunar base
- Inform and involve general public
- Enhance and foster international cooperation

• Mars Science and Exploration • 3

## Crosscutting Theme



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• Mars Science and Exploration • 4

## ***Mars Science and Exploration Themes***



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### • **SCIENCE**

- Search for past/present life (second genesis)
- Characterize planetary system (geology, hydrology, climate, etc.)
- Understanding history and evolution of solar system through comparative planetology
- Human biological limits
  - Physiology: 1/3g, radiation
  - Sociology
  - Psychology

• Mars Science and Exploration • 5

## ***Mars Science and Exploration Themes***



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### • **SOCIETAL BENEFITS**

- Unite the international community under one common goal
  - Doing something bigger than ourselves
  - The “wow” factor
  - Catalyst for further international cooperation on Earth
- Understanding humanity’s place in the Universe
- Human preservation
- Societal responsibility to explore – any nation/humanity
- Opportunity to create a society promoting international cooperation on Mars

• Mars Science and Exploration • 6

## ***Mars Science and Exploration Themes***



### • **EXPLORATION**

- **Inspire generations to look beyond:**
  - **Ourselves**
  - **Our national borders**
  - **Our planet**
- **Establishing human survivability/ habitation / long-term presence**
- **Human exploration**
- **New perspective on humanity and Earth**

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• Mars Science and Exploration • 7

## ***Mars Science and Exploration Themes***



### • **TECHNOLOGY DEVELOPMENT**

- **Sustaining human habitation and long-term presence**
- **Spinoffs**
  - **Earth preservation (tech developments)**
  - **Identification of alternative and new energy sources and infrastructure**

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• Mars Science and Exploration • 8



## *Mars Science and Exploration Themes*



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- **ECONOMICS**

- Researching new energy resources
- Increase resource base / economic sphere
- Creation of new jobs
- Commercialization
  - Human habitation/Tourism

• Mars Science and Exploration • 9

## *Pre-Mars Responsibilities*



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- Establish a clear Mars plan without abstract goals, such as: 'sometime in the future we will go'.
- Define exact goals and objectives on the Moon.
- Advertise this plan to the general public with clear milestones of achievement.
- Enhance involvement of the general public in the Moon-to-Mars initiative.
- Ease restrictions to international cooperation
- Increase coordination between space agencies

• Mars Science and Exploration • 10

## Pre-Mars Responsibilities



- Establish long term lunar base with mission similar in duration to Mars base.
- Plan for transition to private lunar base logistical support to allow for better use of global space resources.
  - Private contractors managing operation under government oversight.
  - Allows for both scientific and commercial use.
  - e.g. Antarctica

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## Conclusion



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# Mars Settlement and Society

## Working Group Report

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





















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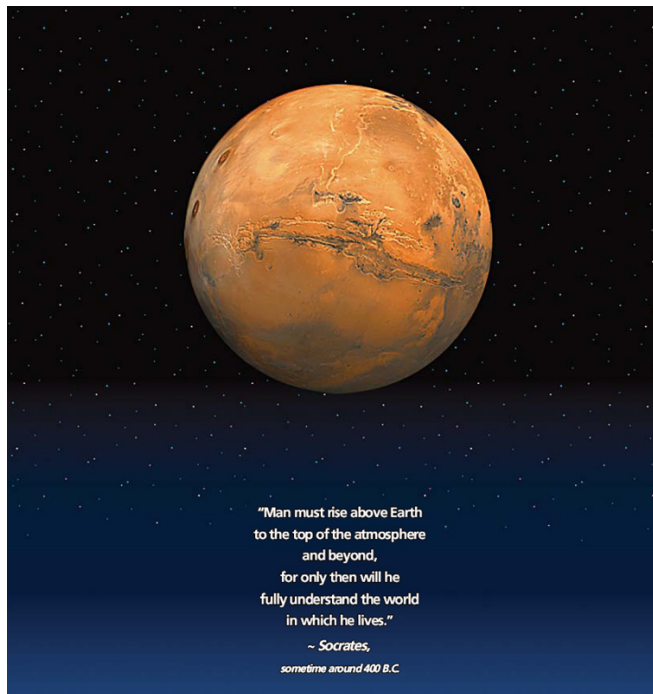
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### Mars Settlement and Society Working Group Part of the Next Generation Exploration Conference

#### Declaration

*The long-term implications of space exploration must be considered early in the process. With this in mind, the Mars Settlement and Society Group focused on five key areas: Philosophical Framework, Community Infrastructure and Government, Creating Stakeholders, Human Subsystems, and Habitat Design. The team proposes long and short term goals to support getting to and then staying long-term on Mars. All objectives shared the theme that they should engage, inspire, and educate the public with the intent of fostering stakeholders in the exploration of Mars. The objectives of long-term settlement on Mars should not neglect group dynamics, issues of reproduction, and a strong philosophical framework for the establishment of a society.*



#### 1.0 Introduction:

#### 2.0 Themes:

- 2.1 Philosophical Framework
- 2.2 Community Infrastructure / Government
- 2.3 Create Stakeholders
- 2.4 Human Subsystem
- 2.5 Habitat Design

#### 3.0 Objectives:

- 3.1 Philosophical Framework
- 3.2 Community Infrastructure / Government
- 3.3 Create Stakeholders
- 3.4 Human Subsystem
- 3.5 Habitat Design

#### 4.0 Issues and Enablers:

#### 5.0 Action Items:



## 1.0 Introduction

*“Man must rise above the Earth to the top of the atmosphere and beyond, for only then will he fully understand the world in which he lives.” --Socrates*

Socrates uttered these words over two thousand years ago and they continue to resound in the call to space exploration being rallied by space faring nations around the globe. The expansion of humanity beyond the confines of Earth will enable us to learn more about our fragile planet and to expand on our knowledge of life. While years of technology challenges may stand before us, the long term vision for space exploration looks ever outward to the Moon, on to Mars, and then beyond. Humanity dares to envision a future where not only small groups of scientists explore but where societies flourish throughout the Solar System.

With this in mind the Mars Settlement and Society group choose to look beyond the issues of getting to Mars and instead focused on the ultimate goal of sustainable societies consisting of humans living full lives on Mars. By “settlement” and “society” we envisioned communities living, working, playing, and raising families on the Martian surface. Perhaps creating generations of people to whom Earth is not home – children being born and living their whole lives on Mars. In this future vision, Mars will have its own culture and all of the cultural trappings that make up a society.

This long-view of exploration may seem to stretch into the science fiction realm for some – especially considering the immediate technological hurdles that must be crossed to even get to Mars. However, many aspects of Mars settlement bring to light key technology and science issues that need to be addressed now. For example, if the ultimate goal of space exploration is long-term settlement, issues of reproduction and child development in reduced gravity need to be addressed. Even though the realization of this may be many decades in the future we can begin now with science to explore these issues. Another example is what is commonly called crew selection. In short sortie missions or short-duration stays off-world, selecting the most physically and psychologically fit astronauts is achievable. When we look at families of “colonists” relocating to Mars it becomes more difficult to control these factors. Thinking of this long-term problem now allows us to begin research into psychology, long-term health, and other factors in reduced-gravity.

Some key questions that this team addressed;

- Is there extant, or recoverable, life on Mars that represents a second genesis?
- Can humans survive on Mars for long durations?
- Can long-term human settlements be made self sufficient?
- Can Mars be restored to habitability (Martian ecosystem)?
- Can a breathable, oxygen-rich atmosphere be generated on Mars (Earth-like ecosystem)?
- What are our responsibilities in exploration?

## 2.0 Themes

### 2.1 Philosophical Framework

*ACTION: Develop guiding principles for exploration that will enable humans to ethically explore the solar system and beyond, to understand, protect, expand and preserve all life in the Universe,*

*and to move from scientific-driven exploration to societies, not as citizens of nations but as citizens of Earth.*

As an overreaching goal, a philosophical framework needs to be developed that will enable Mars exploration to move from scientific-driven exploration and outposts to self-sustaining, autonomous societies.

One of our basic assumptions is that humans will go to Mars not as citizens of a Nation State but as peoples of the Earth. Relations between the communities of Humanity (Lunar, Earth, Mars, and Beyond) should be conducted as citizens of a common species and not based on nationalism derived from any specific community.

### *2.2 Community Infrastructure / Government*

*ACTION: Develop and implement the governing structure and community infrastructure that allows for both short and long term Martian exploration and settlement.*

A Master Plan for infrastructure and government will include a wide range of activities including, law, security, settlement layout, utilities and communications, education, and establishing a chain of authority.

### *2.3 Create Stakeholders*

*ACTION: Create and sustain stakeholders through active public interest and ownership in the activities, milestones, and people within the space program.*

The base of stakeholders in space exploration is broad including business, politicians, international partners, media, young people, and the general citizenry. Engagement of these groups should go beyond simply educating them to the technology being utilized to realize spaceflight. Creating a public that is invested and excited about the space program is crucial to success.

### *2.4 Human Subsystem*

*ACTION: Develop and maintain subsystems that enhance the quality of human life in long-duration spaceflight and habitation on Mars.*

The human factor in spaceflight is well documented. With longer missions a long-term settlement these factors become magnified. Areas of concern include human physiology and psychology, nutrition, safety, hygiene, and fitness. In addition, settlements will require expanded social considerations such as a need for privacy, entertainment and cultural activities, and spiritual and/or religious needs.

### *2.5 Habitat Design*

*ACTION: Provide the tools and facilities necessary to enable a sustained human presence on Mars.*

The design of living environments will both support and shape the other factors listed above and many of the objectives are the same (i.e. hygiene, communication, transportation infrastructure, etc.). This theme focuses on the design of the physical resources necessary for sustained settlement on Mars.

### 3.0 Objectives:

#### 3.1 Philosophical Framework

**Martian Life – Objective:** Create a philosophical framework for interaction with extant or recoverable life on Mars. **Value:** It is widely accepted that preservation of life is good in all its forms and worthy of respect. This may include plans for the treatment of earth-like as well as second genesis life forms. Mars inherently belongs to its extant population.

**Terraforming and ecosynthesis – Objective:** Create a philosophical framework for the ethical use of terraforming and ecosynthesis. **Value:** The decision to alter existing ecological conditions should be effected by what we find on Mars and not made prior to exploration. Mars does not belong to Earthlings.

**Environment and Preservation – Objective:** Create a philosophical framework the ethical use of the Martian environment. **Value:** An X% of Mars must be preserved intact until our knowledge of it assures that the Martian intrinsic properties are well established and understood. The remaining Y% can be used for human settlement and modified accordingly.

**Military – Objective:** Create a philosophical framework for military and defense activities at a Martian settlement. **Value:** Human presence on Mars will be military free. This shall not prevent the use of military personnel or equipment for scientific research or for any other peaceful purpose.

**Martian/ Earth Relations – Objective:** Create a philosophical framework for the extension of humanity to Mars that seeks to learn from past human experience with parent-nation/ colony relations. **Value:** The frontier occupants of the Mars will not exist as a colony or colonies of the nation states of earth, but as an autonomously governed community(s) of the people of Earth and will serve the highest good of all humanity. When earthlings settle on Mars, Earth will be the mother planet and Mars will be the child. Mars will be Earth-dependent (politically, economically, etc.) until Mars reaches adulthood as determined by the citizens of Mars. Mars will belong to its Martian citizens.

**Human Rights – Objective:** Create a philosophical framework for assuring basic human rights and civil rights across the solar system. **Value:** Human rights and civil rights should not be infringed upon simply based on status as a Martian occupant (Universal Human Rights Declaration).

**Culture – Objective:** Create a philosophical framework for ensuring minimum interference in the development of Martian culture. **Value:** It is the right of the citizens of Mars to develop their own culture independent of outside influence. Martian communities share an organic relationship, functioning together for a common purpose.

#### 3.2 Community Infrastructure / Government

**Government – Objective:** Establish a Multi-National Governing Document/ Body (with an established hierarchy). **Value:** The document should be a charter/ constitution that will establish rights, powers, and the governing structure of the community. The organization will be made of multiple nations that will be led by a principal nation.

Standardization – Objective: Establish standard measurements and units. Value: Establish a common calendar, time measurement, unit system, language and finally develop and implement an international Martian reference coordinate system.

Environment – Objective: Adopt an environmental standard. Value: This would control waste management, promote ways to re-use waste, and minimize negative impacts to the environment.

Law – Objective: Create a Community Order of Authority. Value: Derived from the Constitution and the multi-national council a citizen council at Mars will be established. The laws will come from natural and common law.

Security – Objective: Determine regulations on Armaments for security. Value: Derived from the Constitution and the Multi-National council a

Master Plan – Objective: Establish a ‘Settlement Master Plan’. Value: Develop infrastructure layouts, settlement, locations, and overarching plans for short and long term Martian settlement.

Infrastructure and Utilities – Objective: Develop infrastructure and utilities systems on Mars to aid Martian operations. Value: Utilities can include power generation. Infrastructure can include paved “roads” or transportation systems. These are capabilities required by virtually all activities that will be conducted on the lunar surface.

Communication – Objective: Establish communication abilities. Value: Establish a Ka-band from Martian ground to communication satellite via earth for video and audio capabilities. Create communication network on Martian land. Usage will be both technical and personal use: Personal use will be determined by the people/Martian council.

Education – Objective: Develop and establish education programs. Value: Establish orientation program, lessons learned database, develop infrastructure for graduate studies and research

Emergency Services – Objective: Emergency Evacuation. Value: Safety officer on earth/Mars will establish regulations and procedures.

### *3.3 Create Stakeholders*

#### **Economic Stakeholders:**

Businesses / Private Sector – Objective: Open up opportunities for innovative advertising and revenue-generation activities. Value: Reaches to broader audience and creates opportunities for income generation. Also engages political figures based on economic activity potential for constituents.

Commercialization / Privatization of Space Operations – Objective: Define early the plan for privatization. Encourage non-traditional company participation. Reduce red tape and restrictions on leasing or buying government-created infrastructure and operations. Create benefits to space operations and a timeline. Value: Increases private industry involvement



and interest. Reduces NASA overhead to allow for focus on new products & programs. Increases political support of space programs.

International Partners – Objective: Create a mentorship program to include other nations in the development of mission components/operations. Value: Increases the participation in space operations across nations.

Alternative data users – Objective: Open NASA resources/architecture. real-time access to information gathered by spacecraft for use by private companies (Non-governmental orgs) or people for alternate purposes (Google Earth). Value: Creates a new category of stakeholders that are actively interacting with the data streams and gaining economic value from space activities with little upfront cost for the mission operator.

### Public Stakeholders

Media – Objective: Ongoing, Scheduled, Interactive, First person participation. Engage the public with the regular activities of NASA. Value: Keep space activities fresh in the minds of the public. Keep the people updated on missions.

Mission Planning – Objective: Coordinate and publicize mission planning (features), make it interactive with the public. Value: Provide a continuous public view of what is happening and a sustained public awareness of mission events. Make them have an invested interest

NASA / Public Affairs – Objective: Reduce/remove the barriers of self-promotion at NASA. Value: Give NASA an accessible and personal persona as opposed to an “Elite and Distant” organization

Earth-based Citizen Participation – Objective: Plan for and openly prepare for private citizen participation in space activities and research. Value: Creates opportunity for stakeholder participation in science

Fine Arts Community – Objective: Promote and expand the interaction between the artists and engineers to include more art and music in the space program including artist astronauts. Value: Gives a broader spectrum of people access to spaceflight opportunities and engages the public with nontraditional interactions.

Young People – Objective: Elementary and middle-school students that are early-adopters of technology but have limited resources for funding and limited physical mobility round the globe. Value: Next-generation constituents are introduced to space program for workforce sustainability.

Humans in Space – Objective: Broaden spectrum of people “qualified” for space, commercial/private, cultural/artistic, charismatic, medical/scientific. Eliminate the “test pilot” astronaut stereotype. Value: Increases the “culture” factor of missions and enables public to relate to astronauts, can see themselves there,

### 3.4 Human Subsystem

Physiological Effects – Objective: Understand the affects of the integrated Mars environment, in particular partial gravity, radiation and dust on human performance and

human factors. Value: Keeping humans healthy and at peak performance during extended stays on Mars will require an understanding of how features of the Martian environment affects human health, starting from fundamental biological and physical processes. This knowledge will provide data toward understanding the risk present in the system, aiding the design of mitigation strategies. Studies can provide data points for understanding the effects of gravity levels at 1/3g, the effects of the mixed-type radiation spectrum, and the consequences of exposure to unhydrated Martian dust, none of which can be simulated on Earth, enabling the design and development of countermeasures.

Human Development & Adaptation – Objective: Understand the impact of Martian environments on aging, reproduction, and the capability of returning to earth on multiple generations of terrestrial lifeforms. Value: The proliferation of Martian settlements, colonies, and society will depend on our understanding of long term effects of exposure to the Martian environment, specifically aging, reproductions, and returning to Earth. Long term health concerns such as respiration ailments must also be taken into consideration.

Long Term Health Care – Objective: Determine the affects of the Martian environment on surgical procedures, medication potency and production, and other health care issues. Value: The creation of pharmacies and other long term health care facilities must be preceded by research on the effects of 1/3g on medical treatments and procedures. The effects of radiation and microgravity on medicine during transit to Mars must also be researched.

Psychological Effects – Objective: The affects of long-term isolation, Earth withdrawal, and time-delay on the psychological well-being of a Mars exploration crew must be researched in conjunction with the establishment of “Martian psychology”. An extended mission on the far side of the Moon (away from the view of the Earth and with limited communication) could serve as an analog to the Mars missions. Value: Ensure the short term psychological fitness of early Martian crew members and the long-term well-being of inhabitants on Mars surface.

Diet & Food Variety – Objective: Determine the optimum diet for Mars missions with respect to health, variety, and ease of preparation in a closed environment. In the future establish agricultural infrastructure for continued food production. Value: A healthy diet filled with variety is critical for the physiological and psychological fitness of crews on short term missions. Developing means to continue the production of food with a habitat and colony is critical to settlement growth and effectiveness.

Safety – Objective: Develop and implement effective systems and procedures for fire, chemical, and lab safety. Value: Safety systems are not only important for the physical well-being of crews, but for their psychological benefit as well.

Microbial Life forms – Objective: Understand the impact of Martian environments on multiple generations of terrestrial life forms that impact human health. Value: Increases our knowledge of risks to human health and concomitantly increases our capability to manage, mitigate, or eliminate microbial risks to human health. Improved understanding of accelerated microbe mutation and virulence may help in the development of anti-microbial therapies for evolving terrestrial microbes.

**Time Delay – Objective:** Determine the effects of time delay on mission operations, communication, and crew psychological health. **Value:** Procedures that work under normal conditions may be ineffective with the time delay experienced on Mars. New methods must be explored.

**Pharmacological Labs – Objective:** The effect of 1/3g on earth-made medicine must be understood in order to establish pharmacological labs on Mars. **Value:** The setting up of a pharmacological lab for production of medicines will be needed long-term for a successful and healthy settlement on Mars.

**Biologically Based Life Support – Objective:** Develop biologically based life support system components to support long duration human exploration missions. **Value:** Successful closure of the life support system with ecologically balanced plant and microbial communities will reduce resupply logistics for extended lunar stays and Mars missions and facilitate significant terrestrial benefits, particularly in waste management. Additionally, the presence of plants on board may add to the psychological well-being of astronauts during extended missions.

**Hygiene – Objective:** Methods for maintaining effective waste disposal and personal hygiene in a conservation minded manner. Waste management services include the storage, processing, and (if necessary) disposal of human and manufactured waste. **Value:** The maintenance of personal hygiene is critical for crew morale. Waste management and recycling is necessary for the health of the crew and habitat.

**Privacy – Objective:** Ensure that crew members on near term Mars missions receive a fair amount of privacy despite heavy publicity and mission control monitoring. **Value:** The need for privacy is inherent to human nature and must be maintained in order to preserve crew morale.

**EVA Equipment – Objective:** The development of lighter and more maneuverable EVA suits that can be used effectively in Martian gravity. Recreational EVA suits should also be developed. **Value:** The ability to perform effective and comfortable EVAs for both scientific missions and recreation.

**Implement a Communication Infrastructure – Objective:** A communication infrastructure is a necessity of a Martian settlement in order to enable the use of telemedicine, GPS, telecommunication, and the internet. **Value:** It is important to develop a communication infrastructure for long-term settlement of Mars that enables inter- and intra-planetary communications. During early exploration efforts, a short term installation of satellites around Mars would enable settler access for intra-colony communication.

**Environmental Monitoring – Objective:** Environmental monitoring allows for the local prediction of weather, radiation, solar events, and dust storms. **Value:** Prior knowledge of local environmental conditions may influence the location of habitat establishment.

**Maintaining Personal Links – Objective:** Telecommunication will become a method for Martian citizens to maintain personal links with their earthling relatives, as well as

engaging Earth's public by keeping them involved in Martian activities. Value: Maintaining personal links is beneficial for the psychological well-being of the crew and new settlers. Public engagement ensures Earth's support of current and future missions.

Crew Composition – Objective: Utilize a moon analog of crew selection in order to determine ideal crew composition with regard to both profession and psychological frame of mind. Value: Moon analogs used for experimental crew compositions can lead to improved group dynamics and increased productivity.

Exploration Astronaut Corps – Objective: Initial crew composition should include humans who have both a vested scientific interest en-route (scientific experiments) as well as highly-developed maintenance skills. Value: To ensure mission success while maintaining high crew morale during transit to Mars, the initial exploration crews will need to have a vested scientific interest and knowledge to keep the vehicle operating smoothly.

Commercial Astronaut Corps – Objective: A commercial astronaut corp may consist of private individuals selected and specially-trained to perform duties on the Martian surface and eventually form new civilizations in Mars. Value: Transferring astronaut selection and training to the commercial sector may increase the number of astronauts able to travel to Mars by decreasing government involvement in the process.

Sports for fitness and health – Objective: Astronaut crews will need to minimize the effects of long-duration space flight through strength training and sports. Value: Techniques can be developed to reduce the amount of muscle atrophy that may occur at micro gravity. A greater amount of data can be generated and sent back to Earth from 6-month travel to Mars.

Sports for entertainment – Objective: New Martian societies can create new organized sports at 1/3 g. Value: Fun recreational sports, such as gymnastics, quidditch, human powered flight, and other Martian sports can be envisioned because of its lower gravity. Initially, these activities may simply be stimulating recreational activities for crews. Over time, these activities may grow into full-scale tourist destinations that offer a unique experience for paying customers.

Entertainment and Cultural Activities – Objective: Provide arts, entertainment, and recreation (art, literature, gardening, etc) and other leisure activities for those living on Mars. Value: Arts, entertainment, and recreation maintain the psychological well-being of people working in high-stress environments and over a long period of time will be of great value. Recreation and entertainment can be an added attraction for Martian settlers and tourists.

Spiritual and Religious Activities – Objective: Spiritual activities for mental well-being and relaxation must be accommodated. Value: Meditation, prayer, and other spiritual activities for crew mental health.

### *3.5 Habitat Design*

Science Support – Objective: Systems and facilities will need to be set up and maintained for scientific research studies. Value: Scientific studies will be the grounds for initial efforts



performed on Mars and will serve as test beds for future communities and industries.

**Maintenance – Objective:** Provide tools and parts for the repair and preservation of facilities. **Value:** Providing tools and resources necessary to maintain facilities is critical to a self-sustaining community.

**Industry – Objective:** Lay an infrastructure such that, when industry nucleates and expands, systems will be in place to support industrial operations. **Value:** Industry will be a result of initial scientific efforts and has the potential to sprout economic infrastructure in the infant Mars community. It will be important to lay the groundwork where industry can take root and spread.

**Power – Objective:** Provide power generation capabilities, storage, and redundant power sources. Alternative power sources (solar, fuel cells, nuclear) may be necessary. **Value:** Power will be a basic necessity for virtually all activities on Mars.

**Communication – Objective:** Create an infrastructure which provides communication within the outpost, and between outposts, orbital assets, and other bodies. **Value:** Communication systems and information relays will be vital to sustaining scientific research, long term survival, and the physiological well being of Mars inhabitants.

**Computer Systems – Objective:** Create a technology and computer infrastructure/network which controls the previously listed systems. **Value:** Computer infrastructure and networks will be a basic necessity for many activities on Mars.

**Surface Transportation – Objective:** Develop vehicles, such as rovers, to enable humans to transverse the surface of Mars. **Value:** This capability will be important for activities such as mining, exploring, scientific experimentation, and other mobile activities.

**Launch/Escape – Objective:** Provide inhabitants transportation to access to orbit or journey to Earth and other bodies. **Value:** Launch capabilities will be necessary to facilitate crew rotation, maintenance, emergency evacuations, etc.

**Medical – Objective:** Provide materials and equipment for human health monitoring and care required for health, survival and work efficiency. **Value:** Medical care is a basic human necessity.

**Fire detection and suppression system – Objective:** Provide a system able to detect fire through flame, smoke, etc. and initiate suppression techniques. **Value:** Will minimize risk for crew and equipment.

**Thermal control system – Objective:** Provide a system to monitor and control temperature levels of internal environment and equipment. **Value:** Necessary for crew survival and work efficiency.

**Hygiene materials and equipment – Objective:** Supply materials and equipment for human hygiene. **Value:** Necessary for crew health and work efficiency.

Initial Food & Water Sources – Objective: Provide initial delivery of food and water. Provide resources and supplies to create renewable sources of food and water. Value: Initial food and water supplies will need to be carried from Earth. Provisions will need to be made to create renewable and regenerative supplies for a self-sustaining community.

Renewable and regenerative food sources – Objective: Provisions will have to be in place to support renewable and regenerative sources of plant and animal matter for consumption. Value: Food is a basic human necessity. Proper nutrition is essential for ongoing sustainability.

Renewable/regenerative sources of water – Objective: Use of a similar system like what is currently available can be adapted for the Mars “ecosystem”. Value: Water is a basic necessity for all life in the habitat.

Waste management facilities and processing – Objective: Use of a similar system like what is currently available can be adapted for the Mars “ecosystem”. Value: Recycling of waste products will evolve into part of the water regeneration aspect of a sustainable “ecosystem” and is also “ethically” important.

Primary and redundant oxygen supplies – Objective: Use of a similar system like what is currently available can be adapted for the Mars “ecosystem”. Value: Oxygen is a basic necessity for all life in the habitat.

Primary and redundant “make-up” gases supplies – Objective: Use of a similar system like what is currently available can be adapted for the Mars “ecosystem”. Value: “Make-up gases” are a basic necessity for all life in the habitat.

Environmental monitoring system – Objective: For survival, the environment should be analyzed for potential emergency conditions. Value: For both research and survival, the environment – water, atmosphere, radiation, weather, temperature – will need to be observed.

Mission Design/Planning – Objective: Develop an overall “master” plan for the habitat and supporting systems to include current and future goals. Determine proper use of materials, techniques, and practices for constructability and maintainability. Value: Master Planning will be essential to laying out and constructing the most resource efficient habitat possible.

Location – Objective: Determine a location with convenience, practicality, constructability, and environmental considerations. Value: A proper location will be essential for a resource efficient habitat.

Safe Haven – Objective: Develop and implement a structure to provide a temporary refuge for personnel and required resources. Value: Protection from predetermined excessive danger.

Storage – Objective: Both pressurized and non-pressurized protective facilities for resource storage. i.e: warehousing of fuels, materials, equipment and other necessities. Value: Offsite storage facilities, often with separate environment controls, will be required for resources

with special storage requirements or resources that pose potential health risks and should not be stored in primary habitats.

Modular/ Expendable – Objective: Develop facilities and system with the capability for future expansion and technological growth. Concepts to include inflatable facilities or pre-fabricated facilities (ship and shoot). Value: The most economical and growth efficient habitats will be easily expandable, both in accessible room and in systems.

## 4.0 Issues and Enablers

*“When the unknown becomes known, it catalyzes change, stimulating human thought, creativity and imagination.” National Aeronautic and Space Administration Vision for Space Exploration February, 2004*

Through our discussion several issues and enablers became apparent for successful Mars Exploration.

### 4.1 World Community

It was unanimous that exploration of the Solar System will require a paradigm shift in the current climate of international collaboration. Currently, space-faring nations create separate but complementary missions – cooperating and yet maintaining the separateness of their country of origin. We believe that the farther humanity reaches into the cosmos the more necessary it will be to explore as a whole rather than as distinct parts of humanity. Additionally, space exploration is a task that affects all of mankind and therefore must engage traditionally non-space-faring countries. This concept moves beyond “multi-nationalism” and into a realm of pan-nationalism or Earth-nationalism. There are currently laws in place that make this type of paradigm shift difficult (i.e. ITAR).

### 4.2 Public Interest

This topic was also a common theme in our discussions. The “space race” of the 1960’s had a built in motivation that spoke to the public – a race to the Moon. This race was between both the United States and the Soviet Union and with ourselves – to push the outer envelope of human capabilities. This invigorated the public. Today our task is different. We have already proven the capability to put a human on the Moon and we no longer desire for international competition to be the motivating factor. This changes the means with which we must engage the public. Current public relations seem to focus on two areas: telling the public about spin-off technology and inspiring the next generation of explorers. We feel that this should be expanded to include an overarching vision for human exploration into the next frontier and a concerted effort to teach the wonder of science even for those who will not be the “next generation” of explorers. A public with a passion for the space program will not necessarily need to understand the intricate technology involved in getting us there – it will be enough to have them excited about the human achievement of expanding beyond our planet.

### 4.3 Sustainable Funding

An increased public interest will be one way to ensure sustainable funding; however, it is also necessary to shield exploration from the changing tides of politics. Exploration is such a monumental, multi-generational project that constant shifts in direction will ensure failure.

## 5.0 Action Items:

There are many actionable items mentioned in the Objectives sections of this chapter. The major action needed in regards to Mars Settlement and Society is that there needs to be more focus on the issues presented. Planning only for the short-term goals of returning to the Moon will not prepare us adequately for the next step. By creating an international dialogue now about the long-term implications and philosophy of exploration we will help shape necessary today's science and mission goals. This will improve both the return to Moon and the outbound missions.

1. **Continue to engage the next generation.**
2. **Engage a wider variety of viewpoints.** Leaders in ethics, religion, art and cultural leaders, as well as the scientific community will enrich the strategy for exploration. Exploration might be heavily a scientific task but it is a *human endeavor* and input from various areas of society is necessary.
3. **Use diverse communication tools.** The use of new media outlets that appeal to a variety of generations will increase public exposure to exploration. There is an often unspoken expectation that an organization that can put a man on the Moon should be using the latest cutting edge communications channels.
4. **Work with educators** to design curriculum that not only grooms tomorrow's scientists and engineers but also provides an appreciation for human achievement through exploration.
5. **Create and communicate *why*.** Why are we going back to the Moon? Why are we going to Mars? Focusing only on the how and not the why disenfranchises the public.



# Mars Settlement and Society Working Group



## Next Generation Exploration CONFERENCE

Emerging global space leaders designing  
the future of space exploration.

**August 16 - 18, 2006**

NASA Ames Research Center • Building 3

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## Introduction



- *Is there extant, or recoverable, life on Mars that represents a second genesis?*
- *Can humans survive on Mars for long durations?*
- *Can long term human settlements be made self sufficient?*
- *Can Mars be restored to habitability? Likely to be a CO<sub>2</sub> atmosphere. Enables ecosystems on Mars.*
- *Can a breathable O<sub>2</sub> rich atmosphere be generated on Mars? Enables earthlike conditions.*

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## Settlement Themes



- **Human Subsystem**
  - To develop and maintain subsystems that enhance the quality of human life in long-duration spaceflight and habitation on Mars.
- **Habitat Design**
  - To provide the tools and facilities necessary to enable a sustained human presence on Mars.
- **Community Infrastructure/Government**
  - Develop and implement the governing structure and community infrastructure that allows for both short and long term Martian exploration and settlement.
- **Create Stakeholders**
  - Create and sustain stakeholders through active public interest and ownership in the activities, milestones, and people within the space program
- **Philosophical Framework**
  - Develop guiding principles for exploration that will enable humans to ethically explore the solar system and beyond, to understand, protect, expand and preserve all life in the Universe, and to move from scientific-driven exploration to societies, not as citizens of nations but as citizens of Earth

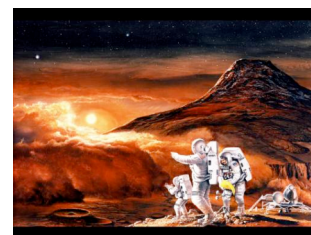
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## Human Subsystems Objectives



- **Human Health and Safety**
  - **Getting there:** Moon analog of isolation
  - **Staying there:** Human development; long-term “Martian” healthcare
- **Life Support and Living Space**
  - **Getting there:** Creating varied menus; lighter, dexterous EVA equipment
  - **Staying there:** Biologically-based life support; private space
- **Communication**
  - **Getting there:** Environmental monitoring for habitat location; communication infrastructure
  - **Staying there:** Internet; weather forecasting for safe operations
- **Crew Selection and Composition**
  - **Getting there:** Vested scientific interest AND “maintenance” skills
  - **Staying there:** Commercial astronaut corps?
- **Recreation and Personal Factors**
  - **Getting there:** Sports/strength training for fitness
  - **Staying there:** Culture, entertainment & new sports



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## Habitat Design



**Theme:** To provide the tools and facilities necessary to enable a sustained human presence on Mars.

**Description:** Develop the capabilities and infrastructure required for shelter, life support, transportation and support systems.

**Shelter** – mission design/planning, location, safe haven, storage, modular/expandable habitat system

**Life Support** – food, water, waste, oxygen, makeup gas, environmental monitoring, medical, fire detection and suppression, thermal, hygiene, move to regenerative systems

**Transportation** – surface, escape, umbilical, launch system

**Support** – science, maintenance, industry, comms, power, computer systems

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## Community Infrastructure/Government



- **Establish a Multi-National Governing Document/Body (With an established hierarchy)**
- **Establish standard measurements and units.**
- **Adopt an environmental standard.**
- **Community Order of Authority.**
- **Determine regulations on Armaments for security.**
- **Establish a Settlement Master Plan.**
- **Develop infrastructure and utilities systems on Mars to aid Martian operations.**
- **Establish communication capabilities.**
- **Develop and establish education programs.**
- **Emergency Evacuation.**

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## Public Stakeholders



- **Media**
  - Ongoing, Scheduled, Interactive, First person participation. Engage the public with the regular activities of NASA.
- **Mission Planning**
  - Coordinate and publicize mission planning (features) to make it interactive with the public.
- **NASA / Public Affairs**
  - Reduce/remove the barriers of self-promotion at NASA.
- **Earth-based Citizen Participation**
  - Plan for and openly prepare for private citizen participation in space activities and research.
- **Fine Arts Community**
  - Promote and expand the interaction between the artists and engineers to include more art and music in the space program including artist astronauts.
- **Young People**
  - Elementary and middle-school students are early-adopters of technology but have limited funding and limited physical mobility round the globe.
- **Humans in Space**
  - Broaden spectrum of people "qualified" for space, commercial/private, cultural/artistic, charismatic, medical/scientific. Eliminate the "test pilot" astronaut stereotype.

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## Economic Stakeholders



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- **Businesses / Private Sector**
  - Open up opportunities for innovative advertising and revenue-generation activities.
- **Commercialization / Privatization of Space Operations**
  - Define early the plan for privatization and encourage non-traditional companies participation.
  - Reduce red tape and restrictions on leasing or buying government-created infrastructure and operations. Create benefits to space operations and a timeline for handing over operations.
- **International Partners**
  - Create a mentorship program to include other nations in the development of mission components/operations.
- **Alternative data users**
  - Open NASA resources/architecture. real-time access to information gathered by spacecraft for use by private companies (Non-governmental orgs) or people for alternate purposes (Google Earth).

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## Philosophical Framework for Exploration



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- The primary goal of space exploration is to understand, protect, expand and preserve all life in the Universe.
- Space Exploration will expand our knowledge to levels which are impossible to achieve if we remain on Earth.
- As an overarching goal, a philosophical framework needs to be developed that will enable Mars exploration to move from scientific-driven exploration and outposts to self-sustaining, autonomous societies.
- One of our basic assumptions is that humans will go to Mars not as citizens of a Nation State but as peoples of the Earth. Relations between the communities of Humanity (Lunar, Earth, Mars, and Beyond) should be conducted as citizens of a common species and not based on nationalism derived from any specific community.



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## *Philosophical Framework for Exploration*



**The Framework will include philosophy on:**

- Interaction with extant or recoverable life on Mars
- The ethical use of terraforming and ecosynthesis
- The ethical use of the Martian environment
- Military and defense activities at a Martian settlement
- The extension of humanity to Mars that seeks to learn from past human experience with parent-nation/colony relations
- Assuring basic human rights and civil rights across the Universe
- Ensuring minimum interference in the development of Martian culture



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## *Conclusions*



**We choose to explore other worlds, establish civilizations, and develop resources in order to ensure the protection and prosperity of all life.**

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# Virtual Worlds and Virtual Exploration Working Group Report

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



















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## Virtual World and Virtual Exploration Working Group

Part of the Next Generation Exploration Conference

### Declaration

*Virtual worlds will forever alter the landscape of exploration, revolutionizing every aspect of research, design, implementation, and resolution—shattering the barriers to collaboration and participation.*

*By providing worldwide access to comprehensive modeling tools, contextual databasing, and interactive collaboration forums, virtual worlds will tap currently underutilized resources and ideas, resulting in an inclusive community of explorers, consisting of everyone from kindergarten classrooms to career researchers contributing to a common goal.*

#### 1.0 Introduction:

- 1.1 Definition of a virtual world
- 1.2 Definition of Virtual Exploration
- 1.3 Current Applications of Virtual Worlds and Virtual Exploration to Support Space Exploration Initiatives

#### 2.0 Themes: Why should we use virtual worlds and virtual exploration?

- 2.1 Support Public Outreach
- 2.2 Generate Environmental Simulations and Effective Data Presentation
- 2.3 Facilitate Communication
- 2.4 Increase Productivity

#### 3.0 Objectives: What to accomplish using virtual worlds and virtual environments?

- 3.1 3-D Computer Sketch Program
- 3.2 Total Virtual Analysis and Design Tool
- 3.3 Virtual Meeting Space: Collaborative Planning and Decision-Making
- 3.4 Virtual Simulation of Unmanned and Manned Missions
- 3.5 Enhance Tele-operation Capabilities
- 3.6 Enhance Data Processing and Analysis via Virtual World Visualization
- 3.7 Augment Data Interpretation via Virtual Environment Simulations
- 3.8 Facilitate Communication between the Public and Experts
- 3.9 Virtual Environment Entertainment
- 3.10 Fully Interactive Promotional and Tutorial Software
- 3.11 Online Depository for Conceptual Designs Submitted by the Public

#### 4.0 Issues and Enablers: Are there devices of society that either impede or facilitate the use of virtual worlds and virtual exploration?

#### 5.0 Action Items: What can be realized now and what are the first steps to implementing virtual world and virtual exploration on a larger scale?

- 5.1 Tools for Dissemination and Representation of Information
- 5.2 Tools for Collaboration and Mission Planning



## 1.0 Introduction

Scientists and engineers are continually developing innovative methods to capitalize on recent developments in computational power. Virtual worlds and virtual exploration present a new toolset for project design, implementation, and resolution. Replication of the physical world in the virtual domain provides stimulating displays to augment current data analysis techniques and to encourage public participation. In addition, the virtual domain provides stakeholders with a low cost, low risk design and test environment.

The following document defines a virtual world and virtual exploration, categorizes the chief motivations for virtual exploration, elaborates upon specific objectives, identifies roadblocks and enablers for realizing the benefits, and highlights the more immediate areas of implementation (i.e. the action items). While the document attempts a comprehensive evaluation of virtual worlds and virtual exploration, the innovative nature of the opportunities presented precludes completeness. The authors strongly encourage readers to derive additional means of utilizing the virtual exploration toolset.

### *1.1 Definition of a Virtual World*

A virtual world is a computer-simulated environment in which one explores or interacts via computers. These worlds may be intended for collaboration, entertainment, or education. While online games are a mainstream example of a virtual world, other examples include detailed virtual representations of part of the lunar surface or virtual conference calls where participants can interact with models to help communicate ideas.

### *1.2 Definition of Virtual Exploration*

Virtual exploration is the interaction of humans with data and models representing reality; it is exploration without being physically present. It was practiced by the first robotic space exploration mission and has been refined ever since. Today, computers can serve as intuitive and efficient interfaces to visualize the results from exploration and scientific experiments.

### *1.3 Current Applications of Virtual Worlds and Virtual Exploration to Support Space Exploration Initiatives*

Engineers frequently use Computer Aided Design (CAD) programs to model components, for system integration, and for testing, thereby reducing development time and cost. However, these software toolsets can be specialized for space exploration missions and expanded upon, thus further reducing time and cost. Similarly, scientists model various physical phenomena—even detailed environments—to explain observations. Once again, improvements in the toolset for modeling will enrich data analysis and interpretation.

In addition, the potential of certain, commonly-used virtual world tools to support space exploration has yet to be fully realized. In particular, the Internet is widely used for business and personal interactions and serves as a resource for entertainment, education, and communication. While information about space exploration activities is already shared over the Internet, it can be done more effectively. The 2-D maps of Google Mars are prime examples of how virtual exploration via the Internet currently aids the dissemination of information about space to the public. These tools can (and should) be improved upon. For example, a 3-D virtual environment of well-mapped regions, which allows users to explore by driving a virtual rover, is more engaging.

### 2.0 Themes

Four primary themes exist to motivate utilization of virtual exploration and virtual worlds.

#### *2.1 Support Public Outreach*

Virtual exploration engages, inspires, and educates the public through interactive, graphically stimulating, virtual replicas of explored regions. The emerging technological tools of virtual presentation, specifically the creation of a virtual environment, enable the public to be contributing members to exploration and discovery. Derivative benefits include, but are not limited to, encouraging students to pursue careers in high technology and scientific fields and ensuring that individuals enter the workforce with the requisite skills and enthusiasm necessary to sustain exploration.

#### *2.2 Generate Environmental Simulations and Effective Data Presentation*

Virtual exploration augments understanding through interaction with environmental simulations and data presentation. Simulations in the virtual domain reveal the nature of complex interactions that are not easily observable in the physical world. Example simulations and their purposes include (1) modeling a stellar environment to explain the spectral observations, or (2) testing technologies, systems, and operations in a virtual environment to streamline mission planning and operations. Effective data presentation techniques improve the understanding of phenomenon and of the correlations between data sets.

#### *2.3 Facilitate Communication*

The interfaces in virtual environments streamline communication between groups essential to the processes of design, implementation, and resolution of a project. Such technologies and processes are useful for projects in exploration, science, and education.

#### *2.4 Increase Productivity*

Virtual exploration increases productivity and has the potential to reduce costs throughout all stages of a mission including planning, execution, and post-analysis. The unique characteristics inherent to virtual environments, such as operations at low cost and low risk environments and as highly visual, multidimensional displays, present new tools for mission stakeholders. By capitalizing on these tools, the stakeholders increase value extraction and realize new values.

### 3.0 Objectives:

While specific applications of virtual worlds and virtual environments are too numerous to identify, below are eleven categories encompassing most objectives for utilizing virtual worlds and virtual exploration. Since virtual worlds and virtual exploration support all stages of a mission, the objectives are listed in chronological order, starting with mission planning. However, the utility of a virtual world does not cease when a mission terminates; with a little creativity, researchers can develop highly-stimulating and engaging software to present mission results to the public. Facilitating public interest and education supports new space exploration missions, eventually leading into planning for the next mission.

### *3.1 Collaborative 3-D Computer Design Program*

Objective: Develop software that allows individuals from across the world to develop 3-D conceptual designs. This tool would have a user-friendly interface and would allow multiple users to contribute simultaneously to a design.

Value: In current practice, individuals brainstorm concepts and designs within groups using simple tools such as whiteboards. Using objects such as virtual whiteboards in this collaborative design program, groups can develop their ideas more effectively and efficiently because the individual contributors are able to modify 3-D conceptual designs in real time, even if they are dispersed across the globe.

### *3.2 Total Virtual Analysis and Design Tool*

Objective: Develop an all-inclusive, fully-integrated tool for design, simulation, and analysis of space-structures. Similar to ModelCenter or to CATIA system, this tool enables virtual assembly, allowing engineers to examine interfaces before costly physical prototypes are manufactured. Moreover, the virtual environment models the conditions a structure will experience in all stages of deployment, including (but not limited to) launch, microgravity flight, and landing, thereby enabling engineers to perform performance estimates.

Value: This tool is a single platform to perform component design, system integration, performance prediction, risk analysis, and mission planning for space-bound vehicles. The comprehensiveness of the software not only identifies the need for redesign, but also eases component modification and subsequent testing. It directly reduces design development times and costs; and it enables a broader design space, increasing the potential for higher reliability and lower risks.

### *3.3 Virtual Meeting Space: Collaborative Planning and Decision-Making*

Objective: Provide a virtual analog of a conference room with audio/visual presentation capabilities similar to a physical room and with additional tools such as 3-D holographic projections, thus removing location barriers and promoting collaboration among geographically dispersed project members. This allows all parties involved to view and to critique material presented by interacting with the virtual environment.

Value: A virtual meeting space can eliminate substantial cost, time, and logistics associated with travel and lodging, which enables more geographically diverse participation. It can also improve communication and allow participants to better visualize ideas presented as a result of 3-D technology.

### *3.4 Virtual Simulation of Unmanned and Manned Missions*

Objective: Use data collected from previous missions to create virtual simulations of equipment and physical environments in which designers model missions before they occur and accumulate experience in an environment that closely simulates reality. Such simulations allow both testing of autonomous robots and assist in planning for human missions.

Value: Virtual tools can supplement physical analogs used for training of humans and

autonomous vehicles. They are preferable to physical analogs because they allow groups to debug and test concepts in a virtual environment without the risk of damage to the equipment and because they reduce training costs.

### *3.5 Enhance Tele-operation Capabilities*

Objective: Use data collected from previous missions and the current mission to create virtual simulations of equipment and physical environments in which operators manipulate and control remote systems. As new mission data and device feedback are incorporated into the virtual environment, researchers increase their awareness of the position and the capabilities of the equipment. In addition, these virtual worlds can assist in debugging and repairing mission glitches, if necessary.

Value: For certain exploration applications, human presence is not required and tele-operations are sufficient, thus reducing the mission cost and risks. Virtual exploration enhances the execution of tele-operations, thereby increasing the level of complexity suitable for tele-operations.

### *3.6 Enhance Data Processing and Analysis via Virtual World Visualization*

Objective: Employ the diverse arrangements for data presentation in virtual worlds, and use virtual environments and interfaces to format, process, and analyze data more effectively for mission operations, science, and outreach.

Value: The way that data is presented influences which results are evident. Often charts and graphs are used to demonstrate trends when a table is unclear; in virtual worlds, data presentation can be fully 3-D and is not confined to 2-D analogues or perspectives. Moreover, virtual worlds can also play with variables such as time or decision points and provide various scenarios and potential futures. Various stakeholder communities can adapt the presentation of the data in a virtual world to suit their needs.

### *3.7 Augment Data Interpretation via Virtual Environment Simulations*

Objective: Model environments and simulate their evolution to recreate conditions that agree with observations.

Value: Often researchers must infer conclusions from the gathered data; however, a clear correlation between the data and its meaning does not always exist. Inferring planet or solar system evolution are two immediate examples of when this correlation is absent. By allowing virtual models to evolve under various circumstances and by examining the equivalent observational data in the evolved world, researchers can infer additional meaning from the data.

### *3.8 Facilitate Communication between the Public and Experts*

Objective: Provide interested individuals with additional means to interact with experts through live sessions and correspondence in virtual environments. For example, augment traditional chats and forums with graphical sketch tools or with models in a 3-D virtual environment.

Value: Virtual environments can enhance direct information exchange from the professionals to enthusiasts and members of the general public with a casual interest.



### *3.9 Virtual Environment Entertainment*

Objective: Produce Omnimax, simulator, and virtual reality rides to demonstrate mission accomplishments and to educate the public. A more extreme example of virtual environment entertainment, one which follows the current trends in television programming and employs the philosophy of the traditional SIM computer games, would be to develop a Virtual Martian Awareness Reality Show (V-MARS) in which contestants would learn to survive in the harsh environment.

Value: Virtual reality rides and reality shows can increase public interest in and awareness of space exploration.

### *3.10 Fully Interactive Promotional and Tutorial Software*

Objective: Utilizing the graphically-stimulating and multi-dimensional benefits of virtual worlds, produce an interactive virtual mission. The mission destination in the virtual world will use real mission data to replicate the physical destination (such as the Moon or Mars) and will use engineering principles to replicate the exploration process. Users control various mission elements, such as launching spacecraft, driving a rover, or docking. Moreover, users make simulated discoveries with the virtual instrumentation.

Value: The software would engage the public and increase interest in specific missions and space exploration in general. It would also educate and place the mission purpose and findings in context for the public to better understand the motivations for supporting exploration missions.

### *3.11 Online Depository for Conceptual Designs Submitted by the Public*

Objective: Create an online warehouse or library where the public can submit and review ideas, in particular conceptual designs. Both solicited and unsolicited projects can be posted to this location for organizations to review and to adopt for further consideration.

Value: By allowing an avenue for the public to design space missions, space agencies foster an environment that stimulates creative ideas and that entices public participation and support. Moreover, agencies open the door to a range of innovative concepts.

## **4.0 Issues and Enablers**

As virtual worlds open the door to new levels of collaboration and interaction for a diverse range of interest groups, it inherently presents an assortment of roadblocks before reaping the benefits of its implementation. In addition, virtual exploration also faces some more traditional obstacles. The following list, though not comprehensive, identifies major barriers to a variety of virtual world and virtual exploration applications:

- Software can be unfamiliar to new users, leading to disuse.
- Software needs to be widely distributed to be effective.
- False data can be integrated easily into a virtual world without being noticed.
- Free flow of information between individuals and groups is limited by barriers of language and knowledge export controls.
- Abuse of intellectual property can happen in a public domain.
- It can be difficult to extract credible ideas or useful information from large databases.

- Collaborative virtual environments can also be used by organizations that threaten national security.
- Large programming projects can become redundant, wasteful, and ineffective.
- There is currently not a strong enough financial incentive to develop some of these technologies.
- It is difficult to code the complexities of the physical world, including physical laws and human psychology, into a simulated, virtual domain.
- Projects will require massive amounts of processing and storage facilities. Who operates these facilities? Who owns the data contained at these facilities?

One should recall that, while the above roadblocks are associated with virtual world development or virtual exploration, they do not apply to all forms of and all uses for virtual worlds and virtual environments.

Similarly, certain trends in society are conducive to developing the potential of virtual worlds and virtual exploration in support of space exploration. These include:

- The popularity of websites to convey near-real-time information to the public on demand, such as with the NASA Mars Pathfinder mission and the first Space Shuttle mission after the Columbia accident.
- Existing software for communication and collaboration between geographically dispersed users.
- Extensive use of the Internet for entertainment, education, and communication, both business and personal.
- A strong public interest in gaming technologies, especially those which more accurately mimic reality.
- The common engineering practice of using software for component design, integration, and testing.
- The need within space agencies to more effectively communicate to their stakeholders that allow an element of participation.

### 5.0 Action Items:

The potential of virtual world and virtual exploration technologies has yet to be realized. The potential of virtual world and virtual exploration technologies has yet to be realized. With comparatively little effort, engineers, scientists, managers, and the public can begin to reap the benefits of space exploration in the virtual domain using existing technologies. As time progresses, interest increases, and as more advanced software tools are developed, more complex interactions in virtual worlds will allow for greater benefit extraction.

#### *5.1 Tools for Dissemination and Representation of Information*

A wealth of data, obtained from missions as far back as the 1960's and from Earth-based observations, provides descriptions of various regions of the solar system. While these descriptions fall short of completeness, they are enough to develop a basic model of the environments. With the necessary resource investment, data can be used to create virtual worlds in which users may immerse themselves. Such environments could then be employed to inspire and instruct the public or to design and test future missions for the regions.

Guidelines for achieving basic information dissemination and representation in the virtual domain with existing technologies are listed below. While the near-term goal is to provide more uniform and optimal access to existing datasets, as the software for virtual worlds and virtual exploration advances, the techniques for data presentation permit more complexity.

- Gather and organize existing data.
- Identify legal issues regarding sharing the data (e.g.. protecting intellectual property or national security).
- Survey existing technologies to identify practices best supporting efficient data distribution.
- Devise a presentation format for the data which is most suitable for the intended audience and objectives. For example:
  - o Maintain a data warehouse for professionals and public;
  - o Develop interactive games for educational purposes; or
  - o Produce a virtual environment that continually incorporates new data to assist tele-operators.
- Modify existing tools and continually develop new tools that most effectively convey the desired information

### *5.2 Tools for Collaboration and Mission Planning*

Once again, technologies exist to facilitate communication via the virtual domain. These technologies are not being used to their full potential. First, agencies engaging in space exploration should use virtual world communication devices, such as the Internet, to collaborate with stakeholders in order to clarify a mission's value and to collaborate with engineers in order to facilitate component design and integration. Guidelines for realizing near-term benefit are:

- Identify the needs for effective collaboration and the requirements for a virtual meeting place.
- Survey existing technologies to identify practices best supporting collaboration.
- Execute trial runs of existing virtual meeting areas, such as Second Life.
- Modify existing tools and continually develop new tools that most effectively allow collaboration among stakeholders, engineers, managers, etc.

Effective collaboration strongly correlates with mission success and productivity, and likewise for effective mission design and planning. Agencies engaging in space exploration should more readily employ the newer, currently-marketed software tools for design, system integration and testing; while these software programs are not the all-inclusive, fully-integrated design tool discussed in Objective 3.2, they are an important component.

To begin development on more complex tools, agencies should:

- Survey existing technologies to identify practices best supporting design and testing of both components and systems.
- Gather experts from various fields to identify the needs of a comprehensive simulation machine.
- Adopt a single, standardized design software toolset for a given mission or project, thus facilitating communication among engineers contributing to different design aspects.

# Virtual Worlds Working Group



## Next Generation Exploration CONFERENCE

Emerging global space leaders designing  
the future of space exploration.

**August 16 - 18, 2006**

NASA Ames Research Center • Building 3

## *What would you do...*

- To make space more relevant to you?
- If you couldn't get there yourself?
- If you had the universe at your fingertips
- If your friends could join you anywhere and anytime!



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## Virtual Worlds are Here Today



- > 10 million people pay \$15/month or more to play online games
- Property right exist in virtual worlds, providing incentive for innovation
- Companies including Wal-Mart, American Express and Intel are experimenting with training and collaboration inside virtual worlds
- Players spent an estimated \$1 billion in real money in 2005 on virtual goods and services within virtual worlds/online games
  - in Project Entropia one player paid \$100,000 in real money for a virtual space station; hopes to earn money charging other players rent and taxes

- **Examples today**



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## Themes



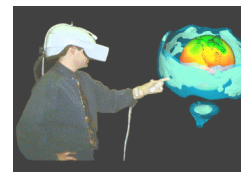
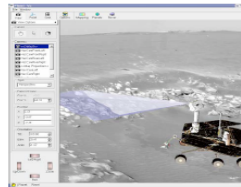
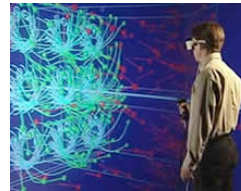
- **Public Outreach**
  - Virtual exploration engages, inspires and educates the public through interactive, graphically stimulating, virtual replicas of explored regions.
- **Environmental Simulations & Presentation**
  - Effective data presentation techniques improve the understanding of phenomenon and of the correlations between data sets.
- **Communication**
  - The interfaces in virtual environments streamline communication between groups essential to the processes of design, implementation, and resolution of a project.
- **Increasing Productivity**
  - Virtual exploration increases productivity during all stages of mission planning, execution, and resolution.

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## Objectives

- **Before a mission**
  - Total Virtual Analysis and Design Tool
  - Fully Interactive Promotional Materials
- **During a mission**
  - Live event coverage
  - Tele-operation
  - Collaborative planning and scheduling
- **After a mission**
  - Post mission analysis
  - NASA Google / Virtual visitor centers
  - Condensed mission highlights (podcasts, YouTube, etc...)



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## Action Items

**Virtual worlds are already here but we must connect the space community**

- **Survey existing technologies (commercial & NASA) to identify useful ones for efficient data management.**
- **Use trial runs of already existing virtual meeting areas (example: Second Life)**
- **Evaluate national security concerns and IP rights**
- **Collect, organize, and analyze existing data for meaningful interpretation as well as future references so data is not lost.**
- **Use virtual world technology to make public outreach more effective through interactive experiences.**



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## Declaration



- **Virtual worlds will forever alter the landscape of exploration, revolutionizing every aspect of research, design, implementation and resolution, shattering the barriers to collaboration and participation.**
- **By providing worldwide access to comprehensive modeling tools, contextual databasing, and interactive collaboration forums, virtual worlds will tap currently underutilized resources and ideas, resulting in an inclusive community of explorers, consisting of everyone from kindergarten classrooms to career researchers contributing to a common goal.**

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














































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















































































































# Next Generation Exploration Conference

Emerging global space leaders designing the future of space exploration



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